1956 NATIONAL CONVENTION

IRE Convention Record

Part 6 Manufacturing Electronics

SESSIONS ON

- Industrial Research of the Future
- The Effects of Environmental and Operating Conditions on the Reliability of "Reliable" Electron Tubes
- Quality Control and Reliability Studies of Electronic Equipments
- Engineering Management Techniques
- Design Approaches with Printed Wiring
- Component Parts I
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- Component Parts
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The Institute of Radio Engineers

IRE CONVENTION RECORD

1956 NATIONAL CONVENTION

PART 6 - MANUFACTURING ELECTRONICS

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INDUSTRIAL RESEARCH OF THE FUTURE

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Summary

Industrial research is a new industry and a new factor in our expanding economy. In the past twenty-five years it has grown from relative insignificance to a 5 billion dollar industry employing some 500,000 scientists, technicians, and other skilled workers. Its rate of growth during this period has been three times that of our economy as a whole and it now represents over 1% of the Gross National Product.

It is predicted that industrial research, which has been tripling in size every 10 years, will continue to grow at a rate that will see it double its present size in 1966 and quadruple by 1976, at which time it will be a 20 billion dollar industry and the basis for an ever-expanding economy.

Industrial research in the past has grown only because it has also become increasingly effective in its techniques and has undergone a far more rapid evolution than the economy it has been helping to create. Its future growth will require still more radical changes in its form and its relation to other industries. During its formative years, industrial research represented little more than a cooperative effort on the part of business men and scientists to transfer to industry the scientific knowledge of our colleges and universities.

Today, industrial research is an integral part of industry and a business in its own right. Its business is the creation of technology, and it has the definite responsibility of knowing what technology is required, creating the particular technology needed, and seeing that it is applied effectively. It does this not only in partnership with the industry with which it is associated but also in partnership with the universities. The creation of new technology requires a continuing and aggressive program of fundamental research to provide the raw materials from which it is fashioned. This, industrial research secures through basic research in its own laboratories and active support of similar work by university scientists.

In spite of its rapid evolution in recent years, industrial research is approaching a new era which will see it change and continue to evolve at an ever-increasing tempo. Many "captive" research organizations will give way to independent research organizations. These organizations will produce technology as their principal product under highly competitive conditions. As this is done, new research techniques will be developed, greatly lowering the cost of creating new technology. This, in turn, will permit the rapid and extensive spread of advanced technology into the thousands of small companies and industries that cannot afford to create their own, thereby strengthening their competitive position and providing the basis for the creation of new industries and new consumers of technology.

Through all this will evolve a new era of industrial growth in which technology will come into its own as our most important raw material and the foundation for an ever-expanding economy.

* * *

It gives me a great deal of pleasure to appear today before a group that has for many years embraced research with outstanding enthusiasm and profit. As President of the Industrial Research Institute and as one who has spent the past twenty-five years in industrial research, I share your enthusiasm and welcome the opportunity to talk to you about it.

While I realize there is little I can add to your own recognition of the importance of industrial research and the part it has played in the creation and growth of industry after industry - including your own - there is another aspect of industrial research that has long intrigued me and which I believe will be of interest to you. What I plan to talk about today is concerned with the future - the future of industrial research - at least as it appears to me.

To look forward you must first look backward a little, and I would like to take you back for a minute to the early 1920's when my company first started a formal program of industrial research. At that time the idea of carrying out such an activity seemed rather speculative, and it was approached on a very modest scale. The effort gradually grew, however, and by the end of World War II we were engaged in what then seemed to us to be a substantial industrial research effort. In spite of this long background and gradual growth, the need for and acceptance of industrial research in my company's operations have resulted in such increased effort that our expenditures for research over the past five years have nearly equaled those for the previous twenty-five.

This is by no means an isolated case, and all industry has seen some startling changes in industrial research activity since many of us started off in this field. While we do not have very exact figures for what was done during those early days, the best estimates we have been able to find are that at the time I started work in 1930 all industry in the United States was spending not more than 2 hundred million dollars to 4 hundred million dollars a year on its industrial research. Today, it is generally agreed that the country's over-all research bill is exceeding 5 billion dollars a year. It does not take much calculation to see that this represents about a 10- to 20-fold expansion and, although some of this has certainly been due to inflation, I think it is obvious that as an industry we are not more than twenty-five years old and that our 1930 effort was indeed small compared to what it is today.

You might be interested in just how large an industry is that spends 5 billion dollars a year and employs some 500,000 people. For comparison, I have looked up a few other well-known industries in the 1955 edition of the "Statistical Abstract of the United States." In this book there is a table showing the value added by manufacture for various manufacturing industries together with the total number of employees involved during the year 1953. Some of these figures are quite revealing, although you should remember that they apply only to manufacturing and do not include other activities of the industry concerned, such as marketing, production of raw materials, etc. The value added by manufacture for the rubber industry is 2 billion dollars and it employs 270,000 people. The manufacturing activities of the petroleum and coal industries together amount to 2.8 billion dollars and employ 230,000 people. For the furniture industry the figures are 2.1 billion dollars and 361,000 people. As you can see, these well-known industries have already been exceeded by industrial research and even such giants as manufacturers of electrical machinery, with 7.9 billion dollars and 1,100,000 employees, or the chemical industry, with 9.3 billion dollars and 768,000 employees, are less than twice the size of our own industry.

On top of this, we are not only a large industry amounting to over 1% of the Gross National Product but are still growing by leaps and bounds. As we look back on what has already happened, we cannot help but wonder what will be the future of an industry that has so far almost tripled in size every ten years.

Of course, we can always do this by extrapolation, and there have been a lot of attempts to do this. The facts are that our country's Gross National Product is growing at the rate of around 3% a year while its industrial research is growing at the rate of some 10% - 12% a year. Already, since 1930, industrial research has risen from less than .3% of Gross National Product to, as I have pointed out, over 1%. If these rates of growth were directly extrapolated, we would wind up with what would, at the very least, seem somewhat fantastic figures for the future of our industrial research effort and its share of our Gross National Product. On the other hand, there is certainly no indication that we have stabilized and there is bound to be a very great growth in industrial research over the next ten or twenty years. As we try to consider all of the factors that might maintain or retard our past growth, it seems to me reasonable to expect that this will be somewhere between the two extremes, and it is my personal opinion that our dollar expenditure for all kinds of industrial research will double during the next ten years and double again in the following ten. Roughly speaking, this will mean that our 5 billion dollar industry will grow to a 10 billion dollar industry by 1966 and a 20 billion dollar industry by 1976, employing directly and indirectly more than 1,000,000 people. Lest anyone feel that these predictions are still somewhat fantastic and will constitute an unbearable drain on our entire economy, I would also like to point out that the economy itself is growing. By 1966 our Gross National Product could reach 6 hundred billion dollars and could by 1976 reach 8 hundred billion dollars. On this basis industrial research, which represents today more than 1% of Gross National Product, would still represent less than 3% by 1976 - a very small price indeed in terms of our total effort if industrial research can continue to be the lever by which our economy is steadily being expanded.

Having made these predictions, I am now forced to tell you that, in my opinion, industrial research as it was carried out twenty-five years ago could never have grown to the 5 billion dollar industry it is today nor, do I think, will industrial research as it has been carried out in recent years ever equal 10 billion dollars in 1966 nor 20 billion dollars in 1976.

When we talk about the growth of research and its possibilities for future growth, I think it is most important for us to realize that industrial research has been changing even faster than the industrial economy it has been helping to create. I am convinced that our growth in the past has been due to the ability of industrial research to become increasingly effective and that its growth in the future will require a continuing and substantial change from our present concepts of how it should be carried out.

As I look back on the early 1930's, it seems to me that to a large extent industrial research was carried out in a somewhat academic and almost mysterious atmosphere, in which industrial research was not very well understood by the company for which it worked and in which the research organization did not know too much about the company. Application of research results to operating problems was almost accidental but very profitable when it occurred. Research in many companies was often carried out mostly because a particular top executive believed in it and the research organization operated as a part of his personal staff. There were even a number of occasions in which the disappearance of the executive who supported research resulted in its disappearance as well.

Today, in modern industrial organizations things are a lot different. Research, today, in a great many companies is regarded as an operating department. It is recognized as a continuing and necessary part of operations and it is generally well understood by the rest of the organization. The research manager is now recognized as a member of the executive team and he and his organization have very definite responsibilities for finding out what is needed in the way of research, for getting the research done, for getting it done on time, and finally for seeing that the results are understood and used by the rest of the company.

Evolution, when you are a part of it, is sometimes difficult to recognize, but I am sure that the research director of the early 1930's would find a lot of changes if he were suddenly transplanted into a modern industrial research organization.

The first thing he might notice would be the preoccupation of research management with over-all company problems. He would sit in on discussions that tried to analyze the future course of the company and to define precisely the need of the company today and in the future for specific technical help. He would see what we now call "Operations Research" at work, and he would see a research management not so much concerned with getting support for specific scientific projects, but with determining just how much research his company really needs and in planning to meet those needs in each specific area. He would see the research organization setting up long-range plans and budgets, scheduling the construction of buildings, pilot plants, etc., outlining personnel requirements, and concerning itself with the development of its future leaders, so that the objectives could be met on time.

The next thing that might catch his eye would be the use of highly-organized teams to solve all sorts of scientific and technological problems with many skills focused on a particular project so that each individual scientist could benefit from the specialized knowledge of his teammates. He would also see an array of electronic calculating machines, mass spectrometers, and other equipment making it possible for the scientist to solve problems in minutes that used to require days of intensive effort. Behind all this activity he would also sense a greatly-increased emphasis on proper management, coordination, and communication, which tie all the complex activities together and make the team an integrated and effective organization.

Next, he would notice another activity which might puzzle him. He would see people throughout the organization busily engaged in translating research results into commercial technology and seeing that it was understood and used by the company. Some of these people would be engineers designing commercial plants, others would belong to what are called "technical service groups" concerned with product-application problems, while others would merely be taking time out from their scientific investigations to talk to plant operators and salesmen and to rewrite scientific reports in a form that would be more useful to other branches of the company.

Everywhere, as he wandered through the research organization, he would have the uneasy feeling that, except for the individual scientist whom he could recognize in the laboratories, he was not in the research department at all but had stumbled into the offices and manufacturing department of an industrial company engaged in turning out some sort of new product. In this conclusion he would have been correct, for that is just what a modern industrial research organization is today. It is a business organized to produce technology and in it are appearing, so far in rudimentary fashion, many of the activities associated with other forms of business, including customer surveys, development of efficient operating techniques, and a form of sales organization.

It is also a business that has not, as many people suppose, neglected fundamental or basic research in its efforts to apply technology to industry. Modern industrial research organizations are keenly aware of the fact that their own raw materials are the basic scientific facts and principles discovered through fundamental research; and within each organization, fundamental scientific studies are carried out for this purpose on a scale much greater than is generally realized. Nor are these studies confined to narrow problems of immediate interest, but often range far afield indeed as the organization continually seeks to develop new products, new markets, and better ways of doing things. Industry also recognizes the traditional and important role of our universities in fundamental research and is taking active steps to see that our universities are given adequate support so that this can continue and grow.

The changes I have discussed in the methods of industrial research have not been brought about without some difficulties. There are still many who feel that this is not a very dignified way of doing business, and they long for the good old days. I do not agree with this and I am convinced that only because it <u>has</u> changed its methods and <u>has</u> become a lot more effective each year has industrial research been able to continue to justify itself on an expanding scale and grow to the stature it now has.

I think that we are about to take another step and that the kind of research that will be a 10 billion dollar business ten years from now will be quite a bit different from our present concept of how it should be carried out. This again will cause a great many heartaches and nostalgic glances toward the early 1950's, but I believe that the changes <u>will</u> take place and that because of them our industry will continue to grow.

If we take a good hard look at what we are doing today, I think it is clear that in spite of all of the progress that has been made we can see that industrial research is largely carried out by what might be called "captive" organizations. Furthermore, these organizations are still highly specialized in their approach to each specific problem and compete only indirectly with one another. If I may use a simple analogy, I would say that we are in the stage of the automobile industry when it was making automobiles by hand. In those days, the cars were of excellent quality but very few people could afford to buy them and the industry would never have grown if it had not changed its methods.

I think the day is fast approaching when industrial research will produce technology as an industrial product in its own right. As this day nears, industrial research will become more and more a separate industry creating an important raw material under highly-competitive business conditions.

It seems evident to me that as time goes on a greater and greater share of our technology will be provided by independent research organizations not attached to specific industrial concerns. These independent research organizations by competition among themselves will establish the competitive market value of various forms of technology and our present "captive" research organizations will remain in business only to the extent that they can compete with the independent groups and do an even better job.

This competition will greatly accelerate the development of improved research techniques, and by freeing our trained scientists from routine work they are now doing will permit them to concentrate on truly creative activities. This will tremendously increase our capacity to make new discoveries and provide technical solutions to an ever-broadening field of problems. Furthermore, as new tools are provided the cost of our new technology will steadily be lowered and find application in many areas where it is now considered too costly.

In particular, I feel certain that as technological services become more and more available on the open market through the growth of independent research companies, entirely new consuming areas will be opened up. These new consuming areas will be the host of medium and small businesses in the country which can then take advantage of the ability of efficient independent research organizations to produce the technology they need at a cost far below that of attempting it in small laboratories of their own. This, in turn, will create new industries and new competitive forces, and both industry and technology will continue to surge forward at an increasing tempo.

I am now coming to the end of my story and would just like to take a few minutes to summarize what I see as I try to look into the future of industrial research in this country. What I see is industrial research as a rapidly-growing and rapidly-evolving industry easily capable of doubling in size in the next ten years and quadrupling in the next twenty years.

I see this growth dependent on the development of greatly-improved research techniques and equipment. These new techniques will not only lower the cost of producing our expanding technology but will have the added advantage that its growth will not be limited by potential shortages of scientific personnel.

I see a new kind of industry which produces technology as a highly-competitive business activity.

I see greatly-increased emphasis on the management and coordination of industrial research, with independent research organizations setting competitive standards and increasing in importance as they develop new and fertile markets for technology.

I see a widespread use of operations research techniques by all industry management and their adaptation to the evaluation of technology itself.

Finally, I see a new era of industrial growth in which technology will come into its own as our most important raw material and the foundation for an ever-expanding economy.

HUMAN RELATIONS RESPONSIBILITIES OF ENGINEERS

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INTRODUCTION

A subject of this nature when assigned for discussion to an engineer or scientist is apt to leave him rather appalled or at best he is reluctant to venture into an area where others seem to be somewhat more familiar.

He is familiar with the precise logic and language which leads to a = bxc. Q.E.D. or a successful experiment in the laboratory which gives very concrete evidence that he has fairly definite control of the most important factors of a given situation. He can look with satisfaction and familiarity upon a gleaming machine which performs its function with silent efficiency, or upon a beautiful bridge which spans a chasm or river. He may even, like a David B. Steinman, be inspired to conceive, design and build a bridge of surpassing beauty as well as efficiency and ruggedness, and then write beautiful poetry about that bridge. There are, however, not too many engineers who achieve such versatility.

THE UNIVERSALITY OF HUMAN RELATIONS

A little reflection, however, on this matter of human relations prompts me to remark that the engineer is as intimately concerned with human relations as anyone else, for he is a human being. He experiences in daily life precisely what every other professional or non-professional experiences.

Hence, this matter of "human relations responsibilities" is not peculiar to an engineer, nor is it basically any different than the "human relations responsibilities" of any other human being. It is universal in all walks of life. That is, it is universal in the sense that we are all encouraged about it during our waking hours and many of us even have sizeable nightmares about it in our sleep. We have even invented frustrations, neuroses and psychoses which indicate its impace on us and our desires to escape.

THE BASES OF GOOD HUMAN RELATIONS

As I stated at the beginning, an engineer or scientist is reluctant to discourse on what appears to him to be so evanescent a subject as human relations. He somehow feels that it involves areas of competency which are beyond him.

For example, he usually disclaims intimate knowledge about psychology and its bewildering array of technical terms and principles. Nevertheless, he usually acquires after many years of experience a good practical working knowledge of psychology in human relations. Unfortunately, he is usually cast out upon the dump heap by management at about this time and his young successor must go through the same laborious cycle before he too acquires this working knowledge.

Essentially what is involved in this area of human relations is an inductive, rather than a deductive process, of coming to a conclusion. When the infinite variety of variables involved in the highly complex human organism—mental, physical, emotional, psychological and spiritual—is recognized, the inductive process covers such a wide field of particular cases and such long time periods that it is not suprrising to find us acquiring only a modicum of competence after a lifetime of experience.

Now this element of complexity is not entirely unknown to the engineer and scientist in his very own fields of technology and science. When the rate of progress in so many technical and scientific areas of knowledge is snowballing so rapidly, or using the mathematician's terminology, is increasing on an exponential rather than a straight line curve, the engineer is certainly not entirely unfamiliar with complexity and extreme breadth in his own field, in general, as well as in his own specialty.

It is germane to the development of our subject to inquire how the engineer is coping with this situation of rapid growth and increasing proliferation.

A good start consists in inquiring as to what is happening in the education of engineering and science students. Here I can speak with some experience, if not authority. The trend here is definitely in a certain direction: a) To recognize that it is impossible to make the young graduate a walking encyclopedia of subject matter, but that he should have first of all a thorough grounding in the fundamental scientific bases; b) To carry this general approach to the selection, presentation and emphasis of his own professional subjects; (c) To include and make an adequate place in the educational program for studies in the social-humanistic area. This is to go beyond, and as far as possible, the matter of spelling correctly and writing of a good engineering report.

In other words, the trend of thinking is to fashion our curricula and the approach to subject matter in these curricula more, rather than less, in the academic tradition. I refer here to the original or historic interpretation of the word academic rather than the interpretation implied in such rather questionable synonyms as "long hair."

I might state that industry is aiding and abetting this type of thinking not only as to a desirable trend in technical education, but also is showing the way in appointing academicians to head its research organizations.

We see in this trend in education for engineers and scientists and in recent developments in industry, at least in research, a realization that the essence of long range planning and action is to concern ourselves first of all with the hard core of basic underlying principles and ideas.

Is it possible to use this as an analogy in an approach to this problem of human relations?

I believe it is and it appears that the fundamentals of human relations are centered in our basic concepts, and adherence thereto, of morality and religion.

If our convictions in these matters have been thoroughly ingrained in us from childhood on and kept alive in our mature years by vigilant, consistent and dedicated action, the problems of human relations will not be onerous or even extremely difficult. Moreover, the individual's responsibilities as to his conduct and participation in human relations will be fairly clear.

A HISTORICALLY AUTHENTIC CODE FOR HUMAN RELATIONS

When this subject was assigned to me and my thoughts developed, it occurred to me that there is one document perhaps as genuinely authentic as any historical document can be which has in it a catalog of the basic elements of a code of human relations. A code which was stated 3,000 years ago and no doubt was itself based on still more ancient traditions and perhaps writings. Since the time of its writing it has been preserved, criticized, advocated, and more or less successfully practiced. I refer to the Book of the Bible known as Proverbs and written by King Solomon.

A CODE OF HUMAN RELATIONS FROM THE BOOK OF PROVERBS

a) Some Fundamentals: Wisdom, Learning and Understanding.

The fear of the Lord is the beginning of knowledge, but fools despise wisdom and instruction.

Incline thine ear unto wisdom, and apply thine heart to understanding.

A wise man will hear and will increase learning; and a man of understanding shall attain unto wise counsels.

Happy is the man who finds wisdom, and the man who gets understanding.

To get wisdom is better than gold; to get understanding is to be chosen rather than silver.

I shall not comment further except to say that these few statements epitomize the belief held by Solomon that wisdom and understanding are highly prized and are attainable if one cultivates receptiveness and is diligent in pursuing them.

Certainly, the very fundamentals of human relations are wisdom and understanding of the human beings with whom we have relations.

b) Evidence of Wisdom and Understanding.

Give instruction to a wise man and he will be still wiser, teach a righteous man and he will increase in learning.

He who heeds instruction is on the path of life but he who rejects reproof goes astray.

Whoever loves discipline loves knowledge, but he who hates reproof is stupid.

The way of a fool is right in his own eyes but a wise man listens to advice.

A prudent man conceals his knowledge but fools proclaim their folly.

He who is slow to anger has great understanding, but he who has a hasty temper exalts folly.

A tranquil mind gives life to the flesh but passion makes the bones rot.

He whose ear heeds wholesome admonition will abide among the wise.

A rebuke goes deeper into a man of understanding than a hundred blows into a fool.

When pride comes then comes disgrace; but with the humble is wisdom.

He who belittles his neighbor lacks sense but a man of understanding remains silent.

c) Some Practical Working Rules for Human Relations found in Proverbs:

Loyalty and Faithfullness

Let not loyalty and faithfulness forsake thee; bind them about thy neck; write them upon the tablet of thy heart.

Generosity

Do not withhold good from those to whom it is due, when it is in your power to do it.

Contentiousness

Do not contend with a man for no reason when he has done you no harm.

Honesty

Put away from you crooked speech and put devious talk far from you.

Do not reprove a scoffer, or he will hate you; reprove a wise man and he will love you.

Hatred

He who conceals hatred has lying lips and he who utters slander is a fool.

When words are many, transgression is not lacking, but he who restrains his lips is prudent.

Integrity

The integrity of the upright guides them but the crookedness of the treacherous destroys them.

He who belittles his neighbor lacks sense but a man of understanding remains silent.

Kindness

A man who is kind benefits himself, but a cruel man hurts himself.

Anxiety in a man's heart weighs him down, but a good word makes him glad.

Temper

A man of quick temper acts foolishly but a man of discretion is patient.

Industry

In all toil there is profit, but mere talk tends only to want.

Charity

A soft answer turns away wrath, but a harsh word stirs up anger.

Moderateness

It is not good to eat much honey, so be sparing of complimentary words.

Modesty

Let another praise you and not your own mouth; a stranger and not your own lips.

SUMMARY

We have called attention to the fact that human relations responsibilities are universal and that the engineer, therefore, has problems and responsibilities which are not unique to the profession of engineering.

The bases of human relations are centered in our concepts and codes of morality and religion.

These codes and concepts are rooted in the experience of the human race. This experience covers not a few years, a few decades or even a few centuries, but goes back many centuries.

Mankind has recorded and preserved his experiences in this aspect of life more consistently and faithfully than in any other area of human endeavor. This attests to the fact that man, therefore, considers such areas as the most important of all others.

In particular, certain quotations were given from the Book of Proverbs in the Bible. These quotations assert that the bases of good human relations lie in learning, wisdom and understanding. They state further that learning, wisdom and understanding may be achieved by devotion, diligence and perseverence. They provide also practical suggestions for achieving working rules in creating and preserving good human relations. An enumeration of these qualities of character and guides for conduct necessary for achieving good human relations reveals nothing new or novel to any of us.

It is somewhat surprising that in this day when we have evolved fool proof checks for thousands of items in complicated mechanisms or processes, we often fail miserably in human relations because we ignore completely one of a very few basic rules of action in this area of satisfactory relations with our neighbors, friends and associates.

Happily there are indications that we are aware of these matters more so than has been true in the past. The challenge presented by a mammoth organized effort which we consider to be fundamentally opposed to and the very antithesis of our deeply rooted convictions in matters of morality and religion may have made them new and more real to us.

Whatever may be the reason for certain indications which represent progress, we cannot relax our efforts and diligence for, in spite of the long experience we have had in these areas, there are great defections in our conduct which result in inequity, intolerance and even abuses of our fellow human beings.

A final quotation from Proverbs appeals to me:

"Remove not the ancient landmarks which your fathers have set."

THE CHALLENGE TO THE ENGINEERING MANAGER

Address by
Clarence H. Linder, Vice President-Engineering Services
General Electric Company
Before the Institute of Radio Engineers
New York City, March 19, 1956

If we stop to listen for even a few moments, we are immediately aware that there are a great many voices being raised today on the subject of the responsibilities and challenges which management should accept. Some of the voices are sometimes strident; some are calm and reasoned. Sometimes, perhaps, they speak without sufficient knowledge whereof they speak; often their message is deeply meaningful for the manager who would achieve business success in the economic climate of today.

Managers, then, do not lack for challenges and many challenges are common to all fields of management. The concept of corporate citizenship, for example, and the principle of operation in the balanced best interests of all groups within the economy are objectives which all managers can enthusiastically adopt. Equally compelling of the manager's attention is the challenging work going on in academic circles, in business organizations, and in societies like the American Management Association, to analyze and define the principles and techniques of the managing activity itself, and to provide for the systematic development of people with genuine managerial ability.

Now all these challenges are predicated on our successful attainment of the tremendous economic expansion and progress we see ahead of us. But there is one challenge which is fundamental to economic success and a particular concern of the engineering manager. It is a challenge which you gentlemen of the Institute of Radio Engineers know as much about, or more, than anyone else. It is the challenge of growth and change in technology -- and I use "technology" in its first dictionary sense: "The science or systematic knowledge of the industrial arts." You are especially knowledgeable about this challenge because electronics technology, around which your interests center, is a vivid instance of a field of knowledge which is growing at an almost explosive rate in both volume and complexity. You contribute to that growth; you strive to keep abreast of that technology; and you put it to fabulously effective use for the benefit of man.

You remember, in classical mythology, that Phoebus Apollo had the authority and the responsibility for driving the team of magnificent horses which once a day drew the great gold chariot of the sun across the heavens from East to West. You also recall, I am sure, what legend says happened on the one occasion when this assignment was left to an amateur. Phaëton, the son of Phoebus Apollo, begged his father's permission to drive one day, and received permission together with detailed instructions about the route and the handling of the horses. Phaëton rashly disregarded the instructions, fell into a panic, and forgot both the names of the horses and how to manage the reins. Knowing the charioteer was not their master, the horses ran away: drying up the rivers, setting the forests on fire and scorching the fields when they veered too near the earth; setting the clouds ablaze when they swerved up toward the heavens. Zeus was compelled to interfere in order to avert complete disaster. In the presence of all the gods assembled, including Phaëton's father, he threw a thunderbolt which killed the boy and brought the chariot to a halt.

I believe this story contains the essence of the challenge to the engineering manager. He is the charioteer. The horses, I hasten to add, are not the engineers who work for him (however much they may think so in moments of exasperation), but the surging, irresistible forces of growth and increasing complexity within technology and the physical sciences from which it springs. As charioteer, the engineering manager undertakes his journey both for the benefit of mankind and to make the enterprise of which he is a part successful. He must chart the course through tangled complexities. He must supply direction of effort to spirited forces of growth so that, as a nation and as companies, we neither dissipate our precious resources in over-enthusiastic pursuit of technological will-o'-the wisps, nor fall behind in the competitive race through technological stagnation. Thus in a very real sense the engineering manager fails to meet or fumbles the challenge of technology at the peril of us all. In a personal sense, his challenge is either to turn the surging forces of knowledge to advantage, or to be run away with and destroyed by them. It is no job for amateurs-he must be Phoebus, not Phaëton.

How is the engineering manager to meet the challenge of technology? What steps can he take to bring together skillfully the great funds of knowledge, understanding and lore; the resources of a business; and the available competence; to the end that economic progress shall result? What I wish to suggest to you today is that he should meet the challenge by applying the principles developed by those who have concerned themselves with the elements of management. In other words, I should like to explore with you a number of aspects of performing the work of a professional engineering manager in a climate of growing, changing technology. There are, of course, a number of definitions of the work of the professional manager, which vary more or less in detail, although they are in substantial agreement on fundamentals. With your permission, I shall use the simple, four-word definition which has evolved for General Electric; these four words are: Planning, Organizing, Integrating and Measuring.

Naturally the scope of this discussion will not permit anything like a complete examination of each of these work areas, but I am confident we shall be able to stake out important and profitable fields to explore in each area. Let me say also at this point that while there is, of course, much challenging and creative engineering work associated with management in the manufacturing and marketing functions of a business, I am going to speak in terms of the product engineering function: that is, the application of technological effort to the conception, development, and specification of marketable products; including, of course, the interpretive work which is an inherent part of the specifying process.

Planning to Meet the Challenge of Technology

Turning first to planning, it would seem that the essentials of planning for the engineering manager are these:

1. To have a charter for his product engineering operation.

2. To contribute, in conjunction with all other functions, to the creating of a product plan for the business; and to know the agreed-upon result.

3. To have a technical plan for his product engineering function.

4. To identify, in the technical plan:

   a) Technical work to be done

   b) Critical technical problems, both continuing and transient.

5. To perceive the dynamics of technology and take advantage of them in planning.

I can certainly make no claim to originality in these statements of the elements of product engineering planning, but I will hazard the opinion that all of us can honestly admit to ourselves that we are not always straightforward and concise enough in our thinking to produce any written statement of them on short notice.

Take for instance the matter of a product engineering charter. A charter is the basic, enabling instrument for the engineering function. It can never be static. It need not necessarily be written, but it should be clearly thought out and carefully kept up to date. Its essential worth can be illustrated if we consider in a general way the elements which it might contain. Here is a fairly representative list:

1. The contributions which product engineering is to make in terms of product determinations, the technology it develops, and the people it trains.

2. The segments of the business enterprise and of the public which product engineering is to serve directly.

3. The fields of activity in which product engineering will have to engage in order to make its contribution.

4. The business resources it must have to make its contribution.

5. The relationships it will need to establish.

6. The rules and standards by which product engineering will govern its activities.

Note that such a charter not only can describe the function of product engineering in the current business of the enterprise, but also can outline the surrounding territory which product engineering should explore with a view to contributing new growth to the enterprise. Thus it serves a dual purpose: as a license for the planned, effective absorption of new technology and, at the same time, as a navigation chart to hold course for the enterprise in the whirling winds of new knowledge.

The product plan and the technical plan must both exist as separate entities -- one for the business as a whole, the other for the engineering manager's operation. Yet for the engineering manager, his contribution to the product plan is inherently inter-related with his own technical plan on a sort of "method of successive approximations" basis. That is, in order to contribute intelligently to the product plan, he must have some general ideas of what he can do with respect to:

1. Applying known technology.

2. Proving the feasibility of applications of new technology.

3. Developing new technology.

Then, once the specifics of the product plan are agreed upon, the engineering manager must refine his ideas in terms of what he specifically must do in these three areas. If we examine some of the detailed steps in technical planning, it becomes clearly apparent why the technical plan is so important a part of the harness for the high strung horses of technology. Here is the way I would state those steps in general terms:

1. Analyze the product plan to determine what technical work needs to be done.

2. Determine what technologies and what specific projects will be needed to do that work.

3. Select those technical work areas and those projects which are sufficiently important to the business to warrant investment of resources.

4. Schedule the necessary work with respect to both people and facilities.

5. Budget the operating costs and facilities required to do the work.

6. Determine the appropriate timing and mechanisms for continuing review and evaluation.

I should like to emphasize for your consideration a few aspects of this technical planning process. First is the fact that it should be complete and detailed. As a handy measurement of these qualities, I suggest that the technical plan, although it is a moving picture, ought to be at any given point in time at least as complete and detailed as the brick-and-mortar plans, the plant layouts, and the financial forecasts we prepare in advance of a capital expenditure.

Next in connection with the technical plan I would stress the tremendous importance of identifying critical technical problems. By a "critical technical problem" I mean one which vitally affects the market performance of the products of a business and which depends basically upon the results of technical work for its solution. When a complete and final solution cannot be foreseen, the problem may be termed a "critical continuing technical problem." On the other hand, the problem may be transient; that is, the corrective answer can be reasonably expected to be found once and for all, or will be required only for a limited future time. Obviously to attempt steps 2 and 3 of the planning process -- determining what technologies and what projects are necessary, and selecting those projects worthy of investing in -- without perception of critical technical problems is flying blind with disabled instruments.

Finally, I would commend to your attention this thought: a static technical plan invites disaster, for the engineering manager and the enterprise he is associated with. To understand the dynamics of technology is perhaps the greatest single talent he brings to his job. With other functional managers and the general manager, he is part of a living entity in a rapidly changing environment. He must be a "quick-change artist" of real ability, for the dynamic technology he works with can overnight obsolete his present applications of the known; or hang a "dead-end street" sign on his projects to demonstrate feasibility; or leap-frog way beyond his attempts to develop new knowledge. And when these things happen nowadays, they often involve an extremely large lock-up of the resources of the business. Have you considered recently, for example, the increasing responsibility of the engineering manager to the general manager for the substance of business decisions which heavily commit the enterprise? Let me offer you an illustration from the aviation industry -- an industry where technology produces obsolescence almost as fast, perhaps, as electronics technology does in your fields of interest. The magazine Aviation Week gives this measurement of the development effort behind two well-known fighter airplanes:

The P-51 Mustang of 1940 required 41,880 engineering man-hours up to its first flight.

The F-86D All weather Sabre of 1951 required 1,131,992 engineering man-hours.

The end function of the product is the same, but there is nearly 27 times the development effort in the more recent model. When we remember that the race to develop this kind of aircraft is almost completely a race of technology, we get a sharp idea of how engineering objectives become very concrete business commitments.

Organizing to Meet the Challenge of Technology

Organizing is the second aspect of professional management work which the product engineering manager must do. Organization is a well-documented and complex subject, and its principles are best described by consideration of individual operations. Therefore, I will confine myself here to some observations intended to highlight factors of importance in an organization built to cope with technology.

As a starting point, let me ask you to accept the premise that a package of work has these constituent dimensions: (1) actions, (2) the objects of those actions, and (3) the amounts of each. On this premise two guide lines can be constructed which are very valuable to the accomplishment of engineering work:

1. Organize to keep actions complete as far as possible; i.e. divide by objects rather than by actions.

2. Organize to conserve scarce skills.

Next I would urge every engineering

manager to look to the relationship channels within his organization. Are they simple and clear-cut? Do they encourage the right kind of communication up, down, and sidewise? Above all, has every man in the place heard -- and accepted-- the definition of his relationship responsibilities to inform and be informed by, not only those above, below and beside him, but also his opposite numbers in other functions of the business?

Then I would repeat that the dynamics of technology influence all the work of the engineering manager -- they are the essence of his challenge. Organization is no exception, and a flexible structure is therefore of the greatest importance -- one which, based on clear-cut relationships and ease of communication, can reform to meet new requirements without creaking at the joints.

One final item of great importance is the need for matching the competence of the man to the requirements of the job so that he is continually challenged, but not overwhelmed. This may sound like a mere statement of the obvious, but I would ask every manager of engineering to remember this fact: We have many, many technical problems before us today which can be solved in a completely satisfactory manner by people with what we may call traditional training and experience in engineering. We also have today a significant number of problems which can be much better solved by people with training in depth in certain disciplines -- training represented by the PhD degree. Let us be sure we know which is which and who is being asked to do what.

Integrating and the Challenge of Technology

The third element in the work of a professional manager we in General Electric have called "Integrating," and perhaps I should take a little time to say what we mean by it. Integrating is a complex concept -- considerably more abstruse than planning, organizing or measuring. In an over-all sense, the integrating work of a professional manager is the bringing and holding together of a multitude of interests, some of which may be divergent, in a harmoniously unified activity with a single set of objectives and joint enthusiasm of effort.

Thus integrating work is essentially concerned with people and the progress they make. The engineering manager must integrate not only the interests and activities of people: but, in another sense, the conflicting demands of technology as well. The integrating work which he does requires the ability to understand, stimulate and lead others; plus imaginative perception of change and potential, and a keen sense of competitive position and timing -- as bases for the allocation of effort.

The manager of engineering is becoming more and more familiar with the essential matter of integrating work under another name -- the team or project approach to complex technical projects. In this approach he has a concrete example of the process of fusing not only diverse personalities, but also a wide range of talents dictated by the technical objective, into a precision-running organization, which gains greatly in capability from the fusion process. The engineering manager, like the athletic coach, contributes leadership to an entity which then accomplishes, through the efforts of others, things the coach could never do himself.

One further point before we leave the team concept: we all know that team-play enhances rather than precludes, the work of star individual performers. On the technological team the role of the outstanding individual performer is growing very rapidly in importance, because of the growth and increasing complexity of technology. It is thus an outstanding challenge to the coach, I submit, to create opportunities sufficiently satisfying and rewarding to attract and hold the team-mates he needs.

Measurement and Engineering Management

The last work element in professional managing is "Measuring." In many ways measurement is the most important work a manager must do and do well, for it supplies either the confirmation or the correction of all his other work. Certainly it takes courage and integrity of a high order to look objectively at the results of one's own efforts; but after all, it is only by the exercise of such judgment that he can be genuinely productive as a manager.

I am sure you will agree with the principle that the more abstract the work is, the more relative the measurement of it must be. Hence there are today few or no absolutes for the measurement of engineering work. The best qualitative measurement I know is periodic comparison of performance with plan -- bearing in mind, of course, the influence of dynamics on the plan.

Measurement becomes, so to speak, the feed-back connection on which the manager is vitally dependent for the means of cutting down the "dynamic" errors of the system. His technical plans, his projects, his technical work-in-progress and his "make or buy" decisions with regard to critical technical problem solutions -- all must be subject continually to appraisal and reappraisal in the light of new, dynamic technology. The skill with which he designs, operates and maintains the feed-back loop has great bearing on his preparedness to meet the challenge of technology.

Conclusion

Planning, Organizing, Integrating and Measuring: these are the elements of the manager's work. We have examined together some of the particular facets of that work with respect to the

This responsibility certainly offers the thrill of challenge and the promise of satisfying reward. The engineering manager who meets the challenge successfully will have concrete evidence of his contribution in the economic benefits we will all share. He will also know he has helped conserve and bring to fruition our physical and technological resources, particularly that most priceless resource, the competence of able and dedicated minds.

challenge which technological change flings at the engineering manager. We have, in other words, done some dissecting of his responsibility for steering our economic progress between an earth-bound course of engineering effort which is "too little and too late" and a course which may set clouds ablaze, but accomplishes little else, because it wastes resources in technologically unproductive areas.

A BASIC STUDY OF THE EFFECTS OF OPERATING AND ENVIRONMENTAL FACTORS ON ELECTRON TUBES

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The responsibility of the tasks entrusted to electronic equipment and the accompanying complexity of this equipment in the last few years have been increasing at an exponential rate. As a result, a great emphasis has been placed on the reliability of the components being used in this equipment. One of the most important components is the electron tube. Although it is usually not the largest in number, the electron tube is one of the most complex of the components and is therefore often the first suspected when trouble develops.

The reliability of the electron tube and its resistance to adverse environments have been greatly improved until today it is not the limiting factor in a great many cases.

A great deal of time and effort has gone into this improvement program. The first co-ordinated approach to this problem was the surveillance programs of Aeronautical Radio, Inc. and others under military contracts. The philosophy of these programs was to study the failures and their causes in operating equipment in the field and to feed-back this information to the tube and equipment manufacturers so that they could improve their products. This approach did greatly improve the performance of electron tubes and equipment, but there are some inherent difficulties with this method:

1. The operating conditions of the equipment may vary from place to place and from time to time. Thus, the exact effects of operating conditions are hard to determine.
2. The maintenance procedures may vary so that the classification of defects may be difficult.
3. The data is obtained from already existing equipment and may not be directly applicable to equipment under development.

These difficulties were recognized by the Electron Devices Division of the Signal Corps Engineering Laboratories. In 1952 they decided on a different approach to this problem which could be correlated with the surveillance programs. This new approach was to make a basic study of the effects of operating conditions and environment. This study was to be conducted with electron tubes under controlled conditions with one operating or environmental condition at a time being systematically changed over a wide range. A contract was awarded to the General Electric Company to conduct this study. It was started in 1952 and has been continuing since that time.

The variables to be studied were:

1. Mechanical Excitation
2. Pulse Operation
3. Ambient Temperature
4. Plate Voltage, Plate Current and Plate Dissipation
5. Heater Voltage and Heater Cycling

The effects of each of these variables will be discussed in the following papers.

Four types of tubes were selected as representative types of reliable tubes. These are the 5654/6AK5W, 6005/6AQ5W, 5726/6AL5W and 6J6W. For simplicity these will be called by single type numbers in the rest of the discussions. To these were added the type 5670 as a pilot type. The pulse investigation used the types 6AG7 and 5814 instead of the 6005 and the 5654.

The tubes were purchased in homogeneous lots from all tube manufacturers who had type approval at that time. The tubes were divided into 200 tube lots with each manufacturer equally represented in each lot and the tubes from each manufacturer were selected by random numbers for each lot. Each 200 tube lot was divided into two 100 tube lots. These 100 tube lots were then run one after the other on the same equipment. Thus, each 200 tube sample which is the basic sample represented two runs of 100 tubes on the same equipment.

A great effort was made to design the equipment to give the maximum accuracy and the minimum of variation. The power was obtained from a sub-station which was on a different power line from the rest of the plant to minimize line variations. The load of the laboratory was 75KVA maximum, and the sub-station was rated at 150KVA. The d-c power was supplied from motor-generator sets with the generators loaded at 50 percent of capacity. All of the a-c except that supplied to the motors on the d-c generators was regulated with a regulator capable of control to 1-1/2 percent. This regulated power was supplied to all of the life test racks and test sets. Each test set had its own regulator to further regulate the a-c. The test set d-c voltages were all obtained from individual regulated power supplies.

A meter calibration set was built which

was equipped with meters of 0.5 percent accuracy. All of the meters in the test sets were checked against this set on a regular schedule, and the complete test set was checked with bridged resistors and a simulating circuit for transconductance after the meters were calibrated. As a control on the accuracy of the test set operators, one engineer was assigned to review the readings. He checked the readings on each tube in each lot against the previous readings on that tube, and also against the readings of the other tubes in that lot at that reading period. When the second 100 tubes were operated, the readings on these were checked against the readings of the first 100 tubes. The tubes were not returned to the life test racks for further operation until the engineer was satisfied that the readings were correct. On any unusual reading which he found he would check the calibration of the equipment and the set-up of the test set. Checks indicate that our maximum reading error is five percent.

The tubes were operated for 5000 hours and were read 14 times during that time. Since the tubes were read on more than one test set they were plugged in and removed from a socket from 80 to 100 times. This excess handling caused several loose pins on the outside of the bub. The rate of occurrence for this was constant and was proportional to the number of insertions in a socket. These tubes were not counted as failures but were counted as good tubes until the time when the pin-failure occurred. All of the tubes that failed were broken open and analyzed. A description of the appearance of the tube was recorded and the failure coded as to probable cause.

Statistical calculations were made from the recorded readings. These statistics were drawn up into curves showing their variations with time. The curves drawn include:

1. Average and standard deviation for all characteristics which were read.
2. Percent of tubes which were not inoperatives. (Inoperatives were defined as tubes which were shorts, opens, or air tubes on which the major characteristics had dropped to 10% of the published bogie value or below, or tubes on which the heater-cathode leakage or grid current was more than 200 microamps.)
3. Percent of tubes which were not inoperatives or were not outside the initial JAN limit for that type.
4. Percent of tubes which were not inoperatives or were not outside the JAN life-test end point for that type.
5. A family of percent survival curves for each characteristic for each type. These are of two kinds. The First Families show the percent of tubes which have not changed more than four different specified percentages from each tube's initial value. These specified percentages for which curves were drawn were 5%, 10%, 25% and 50%. This type of curve was drawn wherever apercentage change of the initial value would be meaningful, such as transconductance or power output. The second kind of survival curve families used was for the type of characteristic where a percentage change would be meaningless, such as grid current, where a large percentage of the tubes would read zero initially. Here the percent survival curves use a set limit instead of a percentage.

Where possible, empirical formulas are being derived for these curves. Since there are 8600 curves on 2900 sheets of graph-paper, it is impossible to present more than a small sample in the time allotted. We have chosen what we believe to be the most interesting of them to show today. In each of the following papers some of the effects of one of the variables studied will be discussed.