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1962 IRE INTERNATIONAL CONVENTION RECORD

PART 10 - EDUCATION; ENGINEERING MANAGEMENT; ENGINEERING WRITING AND SPEECH

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PANEL: SHOULD WE ACCREDIT GRADUATE DEGREE PROGRAMS IN ELECTRICAL ENGINEERING?

Chairman: T. F. Jones, Jr.
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Abstract

In the ASEE and ECPD there has been considerable discussion on the question of accrediting graduate degree programs in electrical engineering. We in electrical engineering need to be informed of the thinking behind the discussion, and this panel brings the issues before our membership.

*Paper follows.

IMPROVING STANDARDS OF GRADUATE WORK IN ENGINEERING

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Summary

Although accreditation of graduate work in engineering was included in the original ECPD directive the need has become critical only recently. R and D employment of engineers now approaches one third of total engineering employment and probably two thirds of those with master's degrees. Research training, which is indistinguishable from education for solving new problems of any type, has been deemphasized at the master's level by elimination of the thesis, by off-campus instruction of a routine or overly specialized nature and by professional emphasis upon the importance of a knowledge of practice. Accreditation of graduate programs would have as a major objective enhancement of the new-problem solving capacity of master's degree engineers. No greater difficulties are found to exist in accreditation of graduate programs than of undergraduate curricula. Improved standards should result.

Introduction

Accreditation of graduate work in engineering has been under discussion for a number of years, in fact, nearly as long as the accrediting process has existed. Although the original ECPD directive included the accreditation of graduate as well as undergraduate work the strains and disagreements inherent in instituting undergraduate accreditation discouraged successive ECPD education committees from consideration of the graduate accreditation problem for nearly a generation. Some ten years ago the question was reintroduced by the writer into the discussions of ECPD, but little progress resulted. Now it appears that the rapidly increasing need for engineers trained beyond the baccalaureate degree with capacity to solve novel problems will force consideration of accreditation of graduate work. This statement required substantiation which will develop as the history and current problems of graduate education in engineering are reviewed.

R and D Employment of Engineers

Just before World War II a survey of large companies indicated that from 10 to 15 percent of engineers were engaged in research and development work. This survey was probably quite incomplete because it doubtless missed many engineers in small operations where the percentage engaged in research would have been negligible. Now, however, the National Science Foundation has just published its 1960 report on Scientific and Technical Personnel in Industry which is based upon rather complete data from the Bureau of Labor Statistics. This report shows that 31 percent of industry's scientists and engineers as a group are engaged in research and development and that 27 percent of all engineers in industry are so engaged.

Each of these percentages must be increased another 6 percent for R and D administration. Hence it is clear that nearly one third of all engineers employed by large and small industry are associated with research and development work. Evidently, even a larger percentage of engineers engaged by government and by universities are connected with research. Now if we may assume that it is twice as probable that an engineer with a master's degree will be in R and D as one with only a bachelor's degree, it follows that two thirds of the master's-degree engineers are probably engaged in research or development work and should therefore be trained specifically for this activity. Comparable figures are naturally higher for the electrical, aeronautical, chemical and metallurgical industries but the percentages drop below the average only for transportation, construction, mining and public utilities. Of course, R and D employment is increasing in all areas.

Training for Research or New-Problem Solving

Except for civil, mining, architectural, electrical-power and mechanical-power engineers all graduate study in engineering should be preparation for research and development or for the solution of new or untyped problems. I would not personally recommend any exceptions but employment figures could be used to justify the exceptions mentioned. My reason would be that training for research or in solving new problems seems to me to be inherently the only unique characteristic separating graduate from undergraduate study in engineering. If additional undergraduate study is essential, it should be provided. If additional undergraduate study is not essential, then it seems best for this country to produce as many bachelor-degree engineers as possible through the shortest acceptable curricula and to distinguish the master's-degree engineer by training him for research, development, creative design or other new-problem solving employment. These are all closely related activities that need not be distinguished as separate graduate-study objectives.

The recent action of ASCE in recommending two types of graduate study, research versus practice, harks back to the historical argument concerning the relative value of theory as contrasted to the art of practice. The teaching of standardized procedures or practice at the graduate level has its only justification in the figures quoted above which show that civil engineers generally have a lower percentage of employment in R and D than most other branches. However, practice changes so rapidly that such art taught in the classroom is largely obsolete. In addition it has a very low transferability since it is far more specialized than engineering science. Finally, practice is taught most effectively on the job, not in the classroom. As a civil engineer I find this concept of practical graduate education to be reactionary and I feel that it will further reduce the attraction of civil engineering to the progressive young engineering minds that have been turning away from the study of civil engineering over the past decade. It is the research fields of engineering that have attracted students in the largest numbers. I believe that preparation for solving new engineering problems has the highest practical value and that the best engineering minds will seek this kind of education. Engineers belong on the frontiers of knowledge. The brightest young engineers will not accept training in practice as a substitute for real graduate education.

Changes in Meaning of the Master's Degree in Engineering

To clarify the need for accreditation to improve the standards of graduate work in engineering one must be aware of the changes that have been taking place rather gradually in the procedures and requirements for the master's degree since World War II. Before the war the master's degree in engineering was normally considered to be a research degree and it usually required an investigational thesis. The post-war bulge overloaded the facilities of many large universities with the result that the number of master's theses to be directed placed a heavy burden upon the faculty. Some departments and colleges reacted by making the thesis optional or by eliminating it altogether. These departments were largely in universities whose liberal arts colleges had adopted the policy of encouraging students to study for the doctorate and who awarded the master's degree as a consolation prize when candidacy for the doctorate was found to be inappropriate. This approach to graduate education has developed into a status symbol for departments in liberal arts and sciences, but it clearly has no place in engineering education where the doctor's degree is still restricted to one or two percent of the profession.

The result in such institutions has been a depreciation of the extent of the research training and experience provided through the master's degree in engineering which has certainly not been replaced by a comparable increase in the number of doctor's degrees awarded. During the first post-war decade industry obtained nearly as many engineers with the baccalaureate degree as it critically needed, but it found itself increasingly short of "new-problem solvers". Whether the question is one of research, development, synthesis, creative design or merely capacity to work in a newly developing field the mind most sought by industry is that of the individual trained to solve unique or novel problems. In contrast, nearly all baccaluareate engineers must be trained to produce standardized solutions. Such training has become relatively of less value to industry as science and technology have been accelerated both by self stimulation and by governmental action.

Sources of Manpower for Solving Novel Problems

Of course, the Ph.D. has become the symbol of the successful problem solver. His research training has provided an open-minded approach and his scientific background has usually been adequate for him to reach out beyond the confines of limited specialization. However, the production of Ph.D.'s has been so restricted that the solution of new problems still forms our most serious bottleneck. With no sharp increase in Ph.D. production likely for a decade or more industry has a very great stake in the problem-solving training of master's-degree engineers. It is not necessary to determine here just what training will provide such engineers with the greatest ability to solve new problems as yet unknown. But it is important to conclude that this ability should be sought through engineering education and that some features of accreditation may contribute thereto. If engineers trained to solve novel problems are not provided by our colleges of engineering in greater numbers, industry will increase its well-known technique of retraining scientists for R and D positions in engineering.

Objectives and Procedures of Accreditation

In considering the desirable features or strengths that accreditation of new-problem-solving graduate programs might enhance it is important to consider the recent growth of off-campus operations. The writer was asked to inspect an off-campus program where six hundred students were registered in graduate engineering courses and all were being taught by the personnel of one company. An engineering college a few miles away had agreed to award master's degrees for this work although it had no graduate faculty nor graduate courses for resident students. A few of the questions that an accrediting committee would raise might be as follows:

Are the students selected or merely accepted?
Is a permanent faculty provided or is it continually changing?
What is the drop-out rate of students?
Are the courses basic in nature or designed to fit company policy?
What are the standards of required work, grading, etc.?
What percentage of the work relates to standardized problem solutions?

Such a simple question as how often does a class meet during a semester can lead to significant information. An accreditation inspection committee would have no difficulty determining the facts involved since teachers freely express their views and are not hesitant in comparing the results of their teaching under different circumstances.

Considering the extreme shortage of research personnel or of those who can solve novel problems the first objective of accreditation should be to encourage development of the research viewpoint in a larger percentage of master's-degree programs. It is doubtless too late to recover some of the ground already lost and it is perhaps not essential in the fields least influenced by research including civil engineering, mining and architectural engineering. But for many fields of engineering the only hope for meeting industry's greatest need is to reinforce the research or new-problem-solving capacity developed at the master's level.

Need versus Resistance to Accreditation

Unfortunately the engineering teaching profession can not universally rely upon industrial encouragement for raising the standards of graduate work. It is understandable that industrial leaders are not experts in analyzing the educational procedures and values that lie behind the letters M. S. and Ph.D. Besides a basic lack of understanding of graduate study by industry, the need for new-problem solvers which these letters are accepted to connote is so critical that discrimination on a quality basis between institutions or between resident and non-resident degrees has virtually disappeared. An employment manager who has had a half dozen vacancies for R and D engineers for several months is not likely to be very critical of an available candidate. The same attitude is rapidly developing in education; if the appropriate degrees are presented, employment becomes almost automatic. Under such circumstances it is essential that an accrediting system for advanced-degree programs be established to enhance the meaning of these degrees, to emphasize to a reasonable extent the importance of the research or problem-solving approach and to remove from the educational institutions some of the extraordinary pressures that have developed to award master's and even doctor's degrees at each industrial location without provision for proper educational procedures.

Conclusions

It can certainly be said that accreditation has increased the standards of undergraduate engineering education sharply without an over-influence upon standardization. Graduate education in engineering, particularly at the master's level, probably has a greater range of quality standards today than undergraduate engineering education had in 1930-35 when accreditation was initiated. Accreditation of graduate work should be no more difficult than accreditation of undergraduate work since its weaknesses and strengths are both readily defined and readily available for observation. Faculty interviews would indicate personnel whose teaching competencies were limited to the undergraduate area. Graduate theses or major reports of graduate students are perhaps more easily evaluated for achievement than routine problem work at the undergraduate level. Certainly this country's greatest educational need is for more engineers who are well trained in the techniques that may be applied to the solution of a host of unknown new problems that industry will face in years ahead. All is not well with the educational world, but research and research training have proved of fantastic value. We are masters of these techniques; let us emphasize our success by building strength on strength. However, we must not restrict the term research training to the concept of high-level Ph.D. education of scientists and a small number of engineers. Engineers must solve great numbers of new problems if technological progress is to be maintained or accelerated. Education at the master's level needed to produce the most effective problem solvers is indistinguishable from that needed by R and D engineers.

THE ROLE OF MARKETING IN TECHNICAL DEFENSE CONTRACTING

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Summary This paper discusses the need for greater integration of the professional capabilities of the engineer and the marketing man in today's increasingly complex and competitive defense market. It emphasizes their separate but complementary roles with the marketing people being essentially the strategists and program planners while the engineer, for all practical purposes, performs the technical sales function. Both are professionals. Each must do the job for which he is best qualified by temperament and experience, yet they must operate as a team. Only in this way will we be able to cope with the increasing pressure of today's defense contracting environment.

Introduction

This decade will see continuing major changes in the technical character of the defense market and an increasing emphasis on better management. Black boxes and systems are becoming unbelievably complex and expensive. With increasing costs goes the demand for ever greater reliability. Engineers are working with materials and physical laws which sort months earlier were only concepts in the research laboratory and, like Alice in "Through the Looking Glass", are having to run faster and faster to keep up with it all. The government is demanding more value for its defense dollar and business is becoming increasingly competitive.

All of this demands higher company efficiencies, particularly in the technical area, yet some managements are noting distrurbing signs that the reverse seems to be true. Selling costs are skyrocketing and technical efficiency is being lost. Despite the increasing complexity of his job, and the urgent need for staying with the state of the art, we find the engineer spending less and less time in the design lab. and becoming increasingly overwhelmed with paper work, technical briefings and outside customer contact. In the absence of good market intelligence technical decisions are often based on inadequate facts and an increasing number of bids are being lost. The cost of proposal preparation continues to rise.

The challenge the industry is facing with these increasing technical demands and competitive pressures is how to get the greatest value from its scarcest resource—the supply of engineers and technical manpower.

Many company managements are solving this problem by a better integration of the skills of marketing and engineering, using the "program" approach to technical sales development. Before going into details of this approach I would like to review some of the current trends in defence contracting which are forcing these changes in management thinking.

Increasing Emphasis on R & D

An examination of defense expenditures over the past few years will show that an ever increasing percentage of available dollars is being allocated to engineering design and development and correspondingly less for production hardware. This is accounted for by the higher costs of advanced development today and by the newer military concepts which place greater emphasis on technical achievement than on the accumulation of large stocks of quickly obsoleted weapons. Although fewer systems are being built the total engineering content is dramatically higher than ever before.

Advanced Concept Engineering

Engineers today are dipping into pools of technology never before available. The sum of scientific knowledge is accelerating at an ever increasing rate, and is spreading out into new fields offering completely new challenges and opportunities for the designer. Just keeping up with current developments is becoming almost a full time job and the need for specialization is being increasingly felt.

Increased Reliability

The cost of failure in today's defense equipment is becoming so great that it can no longer be tolerated. A ten dollar component could conceivably abort a system which cost thousands of irreplaceable man hours to develop and produce—not to mention the cost in dollars. Paradoxically, this increased reliability is demanded despite the unproven state of much of today's technology. Since reliability must be built into the design right from the start this highlights again the need for keeping qualified engineering personnel in the lab. and on the job.

More Value for the Defense Dollar

The increasing cost of sophisticated defense systems is starting to exert tremendous pressure against national resources and is requiring greater allotments of the national budget for defense purposes. This situation of increasing expenditures cannot continue indefinitely in a peacetime environment and we see the government taking numerous steps in a determination to get better value for its defense dollar. Examples are the emphasis on such techniques as Value Engineering, program management methods such as PERT and PEP, and a variety of contractor incentive plans.

The Pressure of Competition

There comes a point where money and manpower resources are the limiting factors in what can be done. This creates intense competition both for the defense contracts and the technical people needed for their implementation. This then becomes a management problem since, when resources cannot be extended, success can only come from getting more value from what is available.

The Problem in a Nutshell

The defense business is getting bigger, more complicated, more expensive, and more competitive. These factors are straining the nation's resources of dollars, technical manpower, and management skills.

What Are We Doing About this Problem?

More and more companies are finding that the best answer in obtaining the kind of efficiencies needed in today's defense markets is a combination of good engineering with planned marketing. This approach divides the overall corporate program into the two basic areas of market development and product development and splits the responsibility between engineering and marketing in such a way that each department does the job for which it is best qualified by training and experience. The engineer is thus enabled to spend more of his time in the design lab. while the marketing manager concentrates on the overall market development utilizing as one of his basic techniques the "program" approach.

What is the Program Approach?

I use the term "program approach" for want of a more suitable name. A program is defined in the dictionary as "A regular plan of action in any undertaking", and that is just about what it amounts to. The program approach is simply step-by-step planning of the marketing cycle with each sale--or potential sale--being regarded as a program which starts with the customer's first tentative requirement and ends only when his needs are fully met, and at a profit to the company. Everything that happens in between is planned, coordinated, monitored and directed by the marketing man with just one objective--to achieve corporate goals through service to the customer.

This cycle from first concept to operating hardware in today's more complex weapon environment can run on for many years. The time span is being even further lengthened by the trend towards the placing of paper studies before design hardware contracts are awarded. Satisfaction of the sometimes conflicting interests of both customer and company management over such long time periods calls for marketing management of a high order.

The marketing "program" approach can be summed up as the application of the concept of "systems management" to the marketing cycle. It is the philosophy of management which insists on complete integration of activities to meet customer needs rather than permitting a disordered series of individual efforts. As contractor-customer relationships tend to develop into long term working partnerships this type of management will become increasingly necessary.

Program Control--A Responsibility of Marketing

In a company oriented to meeting the needs of the customer the marketing manager has many responsibilities. His duties range from the initial determination of market needs, through sales strategy, planning and contract negotiation to the monitoring of company performance to ensure on-time deliveries of fully acceptable products, within the financial limitations of the contract, and at a profit to the company. Even then with complex systems his responsibilities will not end but will continue on through installation, logistics support, repair and overhaul and sometimes to final obsolescence in the field--thus completely closing the market program loop.

An important part of the marketing manager's responsibility consists of coordinating the preparation of the master company schedule which will integrate the activities of all departments and will be reviewed frequently with the customer. He must be alert constantly for the danger signs of missed deliveries or overspending.

The marketing manager's loyalties have to be split several ways. First and foremost he represents his company and, to an important extent, the company's business integrity and reputation are in his hands. He must do everything in his power to maintain company performance at all times.

The marketing man has a responsibility to the customer. In defense contracting he must determine with a great deal of precision what the customer wants, and use the same care in assuring that these requirements are met. In effect he is spending the customer's money and has an obligation to make sure the customer gets good value for every dollar spent.

The marketing man has a responsibility to each of the major company divisions with which he is in close working relationship at all times. Through his personal contact with the customer he can often bail out a department when a delivery has slipped, a specification has not been met, or when a project has been over spent.

The marketing manager without having direct responsibility for the activities of the producing divisions does contribute the planning, the monitoring, and overall control which gives major program continuity and keeps them on the rails. Because the marketing department has no axe to grind it can take an objective viewpoint of the thousand and one difficulties, frustrations, and internal conflicts which always exist on major programs. The marketing manager if he handles these problems with wisdom and discretion can do much to build the team spirit so vitally necessary in any company for good contract performance.

The Role of Marketing in Technical Selling

I think it is in the area of technical selling that the well qualified marketing man can make a major contribution to the company. He can do this by relieving the engineer of a major portion of the sales development which includes a good deal of customer contact, technical briefings, working out of purchase specifications, etc. There is always a tremendous amount of detail and follow-up necessary, particularly in the earlier stages of sales development. In some companies the engineers have had to do such a large portion of the technical sales job as to seriously prejudice their projects in the lab.

It must be realized that in the sale of highly sophisticated products or complex systems the engineer cannot be kept entirely from customer contact. His activities are absolutely essential to the sale. His job is much easier, however, and he can face the briefing conferences and customer contacts with aplomb, if the entire operation is smoothly planned, presentation material well organized, and the right people present at the right time--courtesy of the marketing specialist. This kind of teamwork and planning greatly helps in keeping qualified engineers in the lab. doing the kind of work for which they are best suited.

Engineers ARE Different

There are some engineers who enjoy technical selling and sooner or later we find these people gravitating to the technical selling or marketing end. The average engineer, however, by training, by personal incliation, and by background, has an entirely different makeup from the marketing man. He has different objectives and is appealed to by different status symbols. It has been said that the engineer is more interested in "things" while the marketing man is more interested in people. The engineer, perhaps because of his training, is a little suspicious of any situation which does not lend itself to logical analysis or precise measurement. Both the engineer and the marketing man have to be creative and imaginative but in different ways. The engineer feels that he has accomplished something worthwhile when he demonstrates a black box in his laboratory which is the product of his own creativeness. The marketing man must be of such a personality as to accept less tangible things as a measure of his own achievement. The marketing man is gregarious. He likes people and is more socially minded. The engineer tends to enjoy more the approbation and respect of his fellow engineers. The preparation of a technical paper provides his ego satisfaction; the marketing man finds his when, through planning and interaction with people, he finds himself exercising control of situations.

The engineer on his own in contact with the customer has a tendency to be over precise on small points and the overall sales objective becomes lost. Nearly everything he says tends to be so qualified that eventually he has both himself and the customer confused. He gives the impression of dissembling when, in fact, he is only trying to be highly accurate. The well-trained marketing man tries to communicate understanding, crystallizing the situation into concise and simple language.

The engineer rarely finds interest in the financial aspects of a program, nor does he worry too much about subsequent production, company profits, or other management essentials. The engineer tends to see a relatively narrow segment of the program cycle. The marketing man, because of his training and his wide range of customer and company contacts, has the broader overall view.

Team Work is Essential

The marketing manager in a specialized engineering company has an inherently difficult task. He is dealing with professional men, jealous of their status and often unwilling to accept program direction from men less technically skilled than themselves. This resistance will quickly melt away if the marketing man demonstrates technical understanding with competence in program planning. All along the way the marketing and engineering team must work together each doing the job for which he is best fitted and trained. Each must respect the special skills and capabilities of the other. If the marketing concept is to apply to a business as highly technical as the defense business it must be based on capable people, professionally trained to do their job. With the Engineering and Marketing Divisions working as a team, each with clearly defined tasks and rigid program control, the rate of company growth and achievement will soon convince the most sceptical.

Conclusion

In this paper I have attempted to show how marketing and engineering can work in close harmony to meet customer and company objectives. In doing so and by achieving better utilization of technical manpower the maximum contribution is also made to the nation's defense needs.

THE EVALUATION INTERVIEW

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Summary

The evaluation interview is a satisfying experience for the manager and the employee. Regular interviews are recommended, but the manager must use care and skill if he wants the interview to result in appreciable performance improvement.

Introduction

The "evaluation interview" is a discussion between a manager and his subordinate in which the performance of the subordinate is reviewed. The purpose of the interview is to provide a basis for improving performance and to increase job satisfaction. In our discussion, a "subordinate" (or "employee") is an engineer or engineering supervisor. We shall discuss the attitude of the manager which is most likely to make the interview a success, as well as some of the interviewing techniques at his disposal, and the ecletic view which adjusts the technique to the individuals concerned.

Satisfaction Outweighs Danger

The evaluation interview has become an accepted management activity in many industries. At Westinghouse, for example, every engineer and member of management is evaluated (at least) once each year. There is little doubt in my mind that these interviews are, in general, satisfying to the employee and the manager. In many cases improvement in the employee's performance is quite evident.

The question remains, however, how can the evaluation interview become even more effective and more satisfying? We shall look at some aspects of interviewing which may shed some light on this question. It is only fair to point out that more effective interviews also involve greater risks of degrading the employee's performance as well as the manager-employee relationship. The risk, however, is often exaggerated in the manager's mind to the point where he often avoids the evaluation interview altogether. This reaction by some managers has prompted H. Mayfield[1] to criticize the emphasis placed by some writers on the risks involved in an evaluation interview. He points out that in one survey, over 90% of the employees asked if they would like these interviews continued answered in the affirmative and only 25% answered in the negative, with the rest undecided. He further states that the natural tact of the manager and the employee prevent any unfortunate results. Only in one case (in the paper by Likert[2]) has he come across a supervisor who said, "What I would give to have that hour back!"

I agree with Mayfield that:

1. Rarely does the interview have "unfortunate results".
2. In almost all cases of actual interviews the results are satisfying.
3. Therefore, evaluation interviews should be held regularly.

However, I am not willing to admit that the lone supervisor who wanted so desperately "to have that hour back" is merely the victim of statistics as Mayfield implies when he (talking about this indicent) asks, "Is there a salesman who has not regretted an unfortunate call?"

As an alternative, I suggest the possibility that the interviews mentioned above, and which 90% of the employees wanted to continue was not the same <u>type</u> of interview as the one held by our unfortunate supervisor. I believe it is this fact which accounts for the discrepancy which Mayfield points out, between the forebodings of some writers and the apparent success of actual interviews.

Interview Levels

I have found that interviews reach different levels. There is a pleasant plateau which consists mostly of a get-acquainted process. For the manager, this is pleasant because he learns something of his subordinate as a person, rather than an employee. The subordinate in turn is pleased because his supervisor is taking an interest in him. For the employee this may be called "He-knows-that-I'm-alive" satisfaction. I suspect that many interviews never get much beyond this stage. There may be a pat on the back and a casual remark about possible areas of improvement, but nothing that would seriously disturb the harmony between the manager and the employee.

Performance Improvement Interviews

The interview that succeeds in motivating an employee to substantially improve his performance reaches a far higher peak of satisfaction for both participants. To reach this peak one must often travel a dangerous path. It is up to the manager to learn something of the nature of these hazards and how to cope with them.

The basic problem is that under emotional impact adults often will not react to a situation in the mature, rational manner we would expect of them. Needless to say, most people are emotionally involved when their professional performance is critically examined. As a result, the employee being interviewed may be crushed by criticism or become hostile. In either case the purpose of the interview has been defeated. In almost all cases the manager can prevent both of these reactions without sacrificing the intent of the interview, provided:

1. He has the "right" attitude or disposition towards the interview.
2. He makes judicious use of the available interviewing techniques.
3. He tries to understand what the man thinks of himself.
4. He does not take his preparation for the interview too seriously to keep him from playing part of it "by ear".

Attitude of the Manager

The first of these is by far the most important and probably the hardest to do, even after agreement is reached as to what constitutes the "right" attitude. The manager's attitude is determined to a large extent by his concept of the nature and purpose of the interview, his concept of himself and his subordinate and the relationship of each to the interview.

I submit that in most cases, the "right" attitude is based on the full acceptance of the proposition that the interview is a mutual undertaking between the company (represented by the manager) and the employee for mutual benefit. There are only a few cases where I have found a different attitude more successful. For example, the marginal employee who has not responded to one or more interviews may have to be treated on a "unilateral" basis. In effect his interview takes on the form of setting up conditions for continued employment. The only other exception I have seen is the individual who lacks self-confidence to the point where he wants and needs a paternal approach. Even these employees, if properly handled, will eventually change and be capable of actively participating in the interview.

Looking upon the interview as a mutual undertaking implies some form of agreement between the manager and his subordinate as to the scope of the interview and, in fact, whether or not the interview even takes place.

This may be at odds with the attitude of some managers which is based on the belief that it is his "right" to tell each subordinate what he is doing wrong and why. To be sure, the manager sets the standards of performance. He has the "right" to point out any deviation from his standards as it occurs.

We are not talking of an evaluation interview, which is a review of a man's performance integrated over an appreciable period of time. Since we have excepted the marginal employee, we are left with engineers whose overall performance is thoroughly acceptable. They have earned their salary and are therefore under no obligation to listen to us tell them how they could have earned it better.

Actually, this is no major revision to the interviewing process. The subordinate is told that the scope of the interview will be determined by him and that you are prepared to talk about any aspect of his work and his future to the best of your ability. If he does not want to hear your evaluation, it is probably futile to have one. Usually, however, the employee is eager to have an evaluation interview and, within certain limits is anxious to improve his performance. This does not change the fact, however, that in the case of the good performer, criticism is a privilege and not a right. The manager's attitude on this point affects the material he prepares for the interview, what he says, and even the choice of words and tone of voice. Most employees are sensitive to this attitude and are quick to resent either the "because I tell you so" (dictatorial) or the "I know best what's good for you (paternal) attitudes.

Interviewing Techniques

Once the manager has established the proper emotional background (or "attitude") for himself, completed the evaluation, and discussed the evaluation with his supervisor, he is ready to plan the interview. N. R. F. Maier[3] has placed interview techniques into three convenient categories.

1. The Tell and Sell method.
2. The Tell and Listen method.
3. The Problem-Solving method.

Other methods are certainly possible (e.g. self-evaluation by the employee, committee type interviews, etc.). However, assuming that the immediate supervisor does the evaluation and that the interview will take place between manager and subordinate, these three methods cover the field quite well, although as will be seen, considerable overlap exists between the "Tell and Listen" and each of the other two methods.

The "Tell and Sell" method consists of telling the employee exactly what you think of him, both good and bad. You then tell him where and how you expect him to improve.

The "Tell and Listen" method is similar to the "Tell and Sell" in that you again tell the employee what you think of his performance. In this method, however, you encourage him to express himself and you follow-up on suggestions he makes.

In the "Problem-Solving" approach you encourage self-expression by the employee even more than in the "Tell and Listen" method. You do not express any opinion (unless specifically asked) but rather keep the interview going by asking questions. The only means you have to guiding the interview is by selecting the appropriate questions. Only those questions are permissible in this method which relate directly to a statement made by the employee. At the end of the interview some tangible program is usually available which is aimed at solving a problem. As Maier points out, however, the problem you and your subordinate solve may have nothing to do with his performance.

Maier has two sample interviews in each category, which are analyzed in detail from the standpoint of emotional impact. Since the interviews are of the role-playing variety, rather than real life, the confidence level of at least some of the conclusions is limited. However, the role-players were experienced and, generally, the interviews seem realistic enough.

The results clearly indicate, however, that the "Tell and Sell" method is likely to produce a reaction of hostility or depression in the employee. These were precisely what we wanted to avoid. It should be noted that the interviewers in this case were not satisfied to stop at the "pleasant plateau" mentioned at the beginning of this paper.

The "Tell and Listen" method looks appreciable better, but neither interview using this method is completely satisfactory. The "Problem-Solving" approach worked out very well. In each case, one of the problem areas the manager wanted solved was actually volunteered by the employee. It is a matter for speculation, however, whether the role-acting was not affected by being primed in the problem areas in preparation for the interview. In other words, there is no assurance that in a real-life situation any of the problem areas in which the manager was interested would actually have come up.

Maier recommends a problem-solving approach as the best means of improving performance without risking unnecessary "damage".

I hold to the more eclectic view that the technique should vary to some extent with the individual, the particular problem, and the progress of the interview . There is little chance for the interview to go far wrong if the manager is emotionally receptive to the problems of his subordinate and is sensitive to his reactions during the interview. For example, the manager who has the right attitude does not look upon himself as the fountainhead of wisdom, but as an observer who sees one aspect of a problem and is sincerely seeking help from his subordinate for solving it. He gives his opinion candidly ("Tell and Listen") and is eager to find out what the other side of the coin looks like. He wants to get agreement on the nature of the problem, and recognizing that the employee may be reluctant to disagree with him, he offers several alternatives. (For example, "Do you agree that you have difficulty "getting along" with people in other departments, or do you think I'm looking at a distorted picture? Is it only under certain circumstances or only with certain people? etc.---".) He thus gets his subordinate's point of view. After having agreed on the nature of the problem he joins his subordinate in trying to solve the problem ("Problem Solving"). He is willing to weigh rationally any factor his subordinate may suggest. In those cases (which I have found to be less than one out of five) where the nature of the problem cannot be resolved, mutually agreeable criteria are established for determining the nature, or even the existence of the problem. This I have invariably found feasible. Frequently when this is done the problem (which the manager has observed) no longer seems to exist. Whether the problem never existed or the establishment of criteria had helped solve it is not nearly as important as the fact that one problem area has vanished.

Self-Concept and Performance

Dr. D. A. Prescott[4], noted Educational Psychologist, points out the relationship between performance in school and "self-concept". Self-concept is the image an individual has of himself and his relation to the people around him. The individual's concept of himself may be better or worse in any particular than the concept of him held by others. The relative accuracy of these concepts is is not important to this discussion. What is important is that although the individual may not be able to appraise his performance objectively, his performance will reflect the concept he has of himself. It is therefore important that the manager maintain as nearly as possible, and in some cases, even improve the concept the man has of himself. This is true in the course of daily events, as well as during the interview.

A common example of the effect of this chain of authority-concept-to-self-concept-to-performance is the manager who is afraid to delegate authority. He constantly feels the necessity for checking and monitoring. Under these conditions, no matter how competent the subordinate, he will eventually require all the monitoring (and maybe more) than the manager thinks necessary.

The converse of this is also true. In the article, "How to Fire an Executive", the author describes a manager with many years of service with the company who was to be discharged for "coasting along" and not earning his keep. Top management decided that a graceful way of doing this would be to promote the man into a much bigger job which he obviously would not be able to handle. As it turned out, the man was a resounding success in his new job to the delight of top management.

In this case the man's self-concept had deteriorated over the years due to neglect, and his performance sought the level of his self-concept. Once (he believed) top management recognized his abilities, he lived up to the new image he had of himself.

How is it possible to have an interview in which criticism is given (albeit by permission) without deteriorating the employee's self-concept? Maier suggests that spending many more words on criticism than in praise in the "Tell and Sell" and "Tell and Listen" methods gives a negative slant to the interview. To a large extent this can be neutralized by emphasizing at the beginning and end of the interviews the overall performance.

Another approach I have found useful has been given earlier. If you avoid proving your point (of criticism) but leave it merely an area that you think requires some observation (in some cases close observation) on your part, you give him enough slack to maintain his self-concept.

Playing-By-Ear

No matter how carefully you prepare for the interview you must be ready to change your course. The modified "Tell and Listen-Problem-Solving" approach that I have recommended depends heavily on improvisation. This follows directly from the concept of considering the interview a mutual undertaking and the manager cannot tell in advance how the employee chooses to participate. A good part of the interview consists of searching for definitions of problem areas and for solutions to them. There is also a "reporting" aspect in telling the employee where, based on information you have up to that point, he could improve. There is danger of "overpreparing" this part of the interview. For example, while it is true that you have based your evaluation on as many facts as you had available, it is not always necessary or even advisable to review these facts. You are in the role of advisor, possibly of judge, but never that of a prosecutor. You do not have to prove that your subordinate is guilty "beyond a reasonable doubt". In fact, you have succeeded in your mission if you have raised enough doubt in his mind to make him conscientiously think about the problem. Since this point varies with individuals you want to make your criticism in easy stages trying, as was mentioned earlier, to get the employee to participate. From his reaction, you can gauge your stopping point.

I might add, that not only is it not necessary for you to prove your point, it is usually a decided advantage not to do so. His motivation to improve his performance is higher if he does not feel that your mind is already made up. Another way to deviate from your prepared interview is in the number of shortcomings you discuss. If he has given you reason to believe that he takes your criticism "hard", which can be judged by his initial depression and the time necessary to carry him past his period of depression into a positive, cooperative mood, he probably cannot take any more. You have reached a good place to stop. There is a good chance that he will improve in at least one area.

To get the flexibility that you want in the interview I have found it advisable to quickly run through all comments, positive and negative, casually. In the detail discussion of the improvement areas, I then start with the most important one. If it is necessary to abandon the discussion, the most important item has been covered. At the same time, the others can be temporarily shelved as being of less importance and can be taken up at subsequent interviews. Without the initial run-through, however, there is some risk that the impression will be given that there are not other problem areas to discuss. It may then come as a shock to the employee at some later interview to congratulate him on his improvement and then go on to some "new" shortcomings.

Flexibility should be preserved to allow for discussion on any subject relative to the operation and performance of the department as well as the performance of the employee. The manager may have to alter his concept of the progress of the interview. Generally, there is no complication if the manager has allowed enough time. The interview usually runs anywhere from 30 minutes to three hours. It pays to allow plenty of time, although the interview should not be unduly dragged out.

The manager should keep his ear tuned to the comments made by the employee to determine if anything he says bears on the items the manager had planned to discuss. Depending on what point is made, he may:

1. Lead directly into the subject on his agenda.
2. Decide to drop it from the interview.
3. Approach it from a different tack.

For example, the employee you are interviewing volunteers the information that one of the departments is uncooperative. You had intended to discuss complaints from the department about your employee's irritating habit of "breathing down their neck". You can now lead into the subject you wanted to discuss more gracefully that you could have managed by yourself. But you also have the opportunity to do some information gathering first. You may ask him whether he feels the department as a whole is uncooperative or only a few of its members? Is there any department that he thinks is particularly cooperative?, etc., etc. Having gotten this additional insight into his attitudes, you are now in a much better position to help solve the problem than when you started out.

The fact that much of the interview is "ex tempara" (as opposed to the "Tell and Sell" method, in which the manager knows in advance most of what he will say) does not mean that preparation is unnecessary. In fact the manager must be very well prepared in order to be able to cope with unexpected turn of events and relate these to the man and his problems.

Conclusion

The Evaluation Interview is a useful tool for providing job satisfaction even when it is no more than a friendly talk between the manager and his subordinate. It can also provide appreciable performance improvement if properly handled. There are dangers and difficulties in this type of interview. The employee may become defeated or hostile. Unfavorable reaction can be avoided, however, by having the right attitude towards the interview and by being keenly aware of the effect the interview has on the employee.

Above all, "proper handling" implies that criticism is to be considered a privilege granted by the subordinate, and which may be withdrawn at any time. Unfortunately, it is not always easy to recognize when privilege has been withdrawn during the interview. It is therefore mandatory that the manager remain keenly aware of the employee's reaction to the interview at all times, as this is the only means he has of recognizing the point beyond which criticism is no longer welcome. With the proper attitude and a little skill the manager will find evaluation interviews productive and satisfying.

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TECHNICAL ISOLATIONISM

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Abstract

The exchange of techniques and concepts between specialized technical groups is a growing problem, complicated by factors such as specialized technical jargon, differing terminology and unfamiliar points of view. As specialization grows deeper and more narrow, the expert in one field finds it increasingly difficult to use or even comprehend new developments outside his immediate area.

Various tactics have been used to break down technical isolation within an organization. Technical consultants and staff scientists can often assist the necessary cross-fertilization of ideas and techniques. Transfer of one or more personnel between groups is also found effective. The effect is usually visible in improved techniques and equipment.

ENGINEERS IN MIDSTREAM: A STUDY OF ENGINEERS SEEKING PROFESSIONAL CAREER GUIDANCE

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Thirty engineers sought a consulting psychologist's guidance regarding next steps to take in planning their careers. Although some were referred by their employers, each paid his own way and was dealt with confidentially. Each engineer was interviewed at length, and tested on devices covering many aspects of ability and creativity, interest, and personality. A counseling session and written report followed. The findings and conclusions are presented with the needs of both the individual engineer and the engineering manager in mind.

Introduction

It has often been claimed in engineering circles that better use of engineering talent would help to solve what now appears to be a permanent problem, namely, technical manpower shortage. In line with this claim, many actions and articles have dealt with better technical manpower utilization via procedures simplification, improved communication, better organization, incentive systems, etc. The present study concentrates on the engineer himself. It presents the problems and characteristics of 30 engineers who sought a consulting psychologist's career planning guidance.

The subjects ranged from 30 to 58 in age, up to board chairman in position, and up to Ph.D. in education. The findings carry implications for the individual engineer who has a selfish interest in how best to navigate his own career. They also have significance for the engineering manager who has a personal stake in getting best results from groups of technical personnel, and for the engineering leadership of the country as a whole.

Procedure

Detailed interview

Each interview started with a discussion of the engineer's reason for seeking guidance. Every person's objective was to find out what type of work was best for him, but this overall description of purpose hides much of the flavor that comes from a finer breakdown of reasons. Because of the tremendous individuality and variety of problems presented no classification system really tells the whole story, but the one used, which follows, is helpful:

50% of our sample wanted confirmation of their suitability for a particular phase of engineering, such as management, personnel, R&D, sales, or wanted a general assessment of how their abilities compared with those of other engineers, or wondered whether some field outside of engineering might be better for them. "Limited" success, boredom, feelings of dissatisfaction, insufficient time for family responsibilities were typical underlying factors.

16.7% were quite successful engineers (as later details confirmed) whose problem was precipitated by their success. Typical issues were: Should I accept this offer? I do well at many things, shouldn't I start narrowing down? Here are my plans for further self-development. How sound are they?

13.3% were so dissatisfied or unsuccessful as to come with the hypothesis that perhaps they didn't belong in engineering at all.

10% were stymied in their work and questioned whether it was themselves or their bosses or companies that was at fault.

3.3% had tried to solve their problem by leaving engineering completely, and, because this didn't work, wondered what to try next.

3.3% sought an assessment of aptitude for graduate work in engineering or physics.

3.3% sought ideas for self-improvement.

As might be expected some of these originally stated problems became more complex on further analysis. For example, in several instances concern was shown about how best to discipline the children, how to be a better husband and father, etc.

Other aspects of the interview covered health history, work history, education, hobbies, community activities, aspirations, and various facets of personality. In addition to useful content as such, and impressions about abilities, interests, and personality, the interview provided guidance in selecting tests and interpreting test findings. In several instances the interview provided a cathartic role, as indicated by engineers' comments that the talking out process made them feel a little better already.

Testing

Ten to fifteen hours of testing, distributed over a period of several days or weeks, were used to shed further light on the problem presented. Measurements of ability dealt with knowledge, skills, or aptitude related to supervision, writing, ability to reason with engineering concepts and knowledge, art judgment, mechanical comprehension, reading, graduate school aptitude. Interest and value measurements dealt with money-mindedness, business interests, practicality, esthetic sensitivity, supervisory interest, interest in science, the arts, computational work, etc. Personality and temperament devices shed light on general emotional health, whether anxieties had a recent or remote origin, and the extent to which an engineer demonstrated such characteristics as dominance, planfulness, flexibility, persistence, drive, productivity, conformance, independence, self-reliance.

In line with the most recent research findings creativity was assessed by a combination of ability, interest, and personality tests. For the most part, tests were untimed and objectively scored. As indicated earlier, the selection of tests varied with each engineer.

Counseling

This phase lasted about 1½ to 2 hours in most instances, with some engineers requesting an additional session or two. In it the counselor presented the interview and test findings. Special counseling techniques were used to facilitate understanding and acceptance, to stimulate correct interpretation by the engineer himself, and minimize resistance. Certain findings often raised additional issues and flushed out facts that hadn't been reported in the original interview.

There were many variations in the role played by the counselor. Some of the engineers did an excellent job of interpreting and integrating findings and deciding for themselves what was best for them. At the other extreme were some who had to be taken by the hand practically all the way. Counseling sessions ended with development of short-range and long-range plans, and a playback by the engineer (sometimes spontaneous) to enable the counselor to assess the completeness and accuracy of communication achieved. As one man put it: "Had I known this about myself a year ago I wouldn't have left my $14,000 engineering job to seek greener pastures out of engineering." And another: "I've heard and felt things like this before, but this is the first time I have been able to believe them."

Written report

This was the final phase of the guidance process. Here the counselor put into well-organized form the findings, conclusions, and recommendations developed in the counseling sessions. It also contained "afterthoughts," that is, ideas, interpretations, suggestions that did not occur to the counselor until after the counseling session had concluded. When the counselor is forced to organize his thoughts and put them on paper he can sometimes get insights that did not occur earlier. For example, certain reactions of the counselee may not register until the counselor has a chance to concentrate fully on his materials.

The engineers themselves used the report in various ways. Some used it for further self-analysis. Others used it for resumé preparation, or as a basis for negotiation and self-development planning with their immediate superiors or prospective employers. Occasionally the counselor received phone calls from prospective employers regarding verification of claims made by the engineers.

Findings

General intelligence

The group as a whole was anything but weak on this single indicator of general ability. The lowest scorer was superior to about 80% of the general population on a timed test which was later replaced by an untimed device. Analysis of his answer sheet showed only one error, suggesting that his speed and total score suffered at the price of accuracy. The remaining 29 scored in the top tenth of the general population, and several scored in the top one per cent, and, in so doing, piling up the highest intelligence scores seen by the author in recent years.

Other ability strengths

Twenty-five or 83.3% of the group surpassed the average engineer in one or more abilities considered important to success in some phase of engineering. For example, an engineer who was average to below average in abilities related to success in engineering as such showed outstanding supervisory judgment, a key finding that could be added to other strengths as a basis for re-building his career. Another received, on what may be the most difficult mechanical comprehension test available, a score higher than any reported by the test publisher. Interestingly, this unusually outstanding ability was not being used to advantage in the man's current job.

Engineers "by accident."

Six people (20.0%), on the basis of all findings, could best be classified as "engineers by accident." In four instances the common denominator was math strengths and very high general intelligence. Parental ambition and pressure was also a factor in four instances. What should these people have been? Two should have been in some phase of accounting or finance, two should have been social science teachers, and one should have been a social work administrator. One was a highly intelligent, well-educated salesman who got into engineering when he came to this country after the war, was short of funds, and needed a job badly.

Wrong phase of engineering

More than one-third of the group (36.7%) were rather poorly suited for their present job, but well suited for another phase of engineering. For example, one engineer best cut out for production engineering was beating his brains out, quite unsuccessfully, in a sales assignment. Interestingly, he grabbed this job to get away from his former job (in the same company) which bored him because it consisted mainly of handling paper work in the office. A classic example of jumping from the frying pan into the fire. Another, brilliant generally as well as mechanically, clearly belonged in development work. He had gotten into personnel work, for which he was pre-eminently unsuited, apparently because of extreme conscientiousness, ability to get a job done, and a rather naive missionary zeal regarding people at a time when an equally naive management needed strength in the office.

Right phase, but---

Almost half (46.7%) were best suited for their present work, but had certain limitations that hampered their effectiveness and saturated the green of the pastures elsewhere. Counseling session developments illustrate this very well. One man's reaction to total findings was: "The more you talk, the more you sound like my boss." And another: "Well, it seems that I'm best off if I stick to my present type of work, in my present company which, by the way, doesn't seem so bad after all." What these people needed mostly was better self-understanding coupled with suggestions for self-improvement.

Hidden talent exposed

About one out of four engineers (26.7%) learned of an outstanding strength of which they were unaware, the knowledge of which could be used to advantage in an engineering job. One, for example, had gotten a degree completely via the evening school route, while holding jobs starting with machine operator, and working up to machinist and electronics engineer as such. On a test for helping to assess graduate school potential he was superior to 99% of engineers enrolled in graduate degree courses. This knowledge, as follow up showed, gave him confidence to take certain actions. He felt that some of his past self-improvement actions, which now struck him as misguided, came from a long standing self-concept of being probably "a little dumb," and "average at best."

Emotional problems

One-third of the engineers were free of emotional difficulties of recent or remote origin. This is another way of saying that they were rated by the author, on the basis of rather extensive data, as having very well adjusted personalities. One-tenth claimed prior psychotherapeutic assistance. This figure is about average when compared with general population norms for the country as a whole.

Two-thirds of these engineers could be described as having emotional difficulties. Some difficulties were essentially job situational, others were of remote origin, some were family situational, and some were sufficiently complex in origin to defy any simple classification scheme. Psychotherapy was advised in only two instances. One reason was that it wasn't considered necessary. Another was that while it might prove helpful, other actions, such as job changes, appeared of equal or greater value.

Creativity

Because a fuller assortment of creativity assessment devices were available toward the end of the study than at the beginning, it is not possible to report on the creativity of the group as a whole. However, among those of highest general intelligence, from whom the greatest creativity was theoretically possible, we had some engineers who showed high creativity, and some who showed low creativity. Widely accepted criteria of creative performance, for example, 47 patents, and test findings on instruments known to be valid, were used as creativity indicators. Because of the well known limitations of patents as a sign of creativity, it is stressed that they were not the only indicator employed.

Follow-Up

Scanty to full follow-up data are already available on more than two-thirds of the engineers studied. Such information sheds further light on the value of the counseling process. It also must be considered as evidence rather than proof to avoid the post hoc fallacy. Theoretically, whatever action these engineers took after counseling might also have been taken without going through the counseling process.

In twenty of the 22 instances in which follow up facts are available, it appears that the engineer acted well within the framework of findings and recommendations. Here it must be remembered that the recommendations were made by the engineers themselves in many instances and "seconded" by the counselor. However, there definitely were instances where the counselor was the primary source of a suggestion.

Here are examples of acting within the framework of findings and recommendations:

- Returning to the field of engineering.
- Leaving engineering personnel administration and returning to R & D.
- Leaving sales and returning to R & D.
- Sticking to the present job and being promoted in same line of work.
- Leaving engineering and being promoted into a related job that is primarily managerial and administrative in nature.
- Quitting job and entering business for self.
- Remaining on present job, and going to graduate school.

Of the two people that did not act in accordance with the findings, one claimed that private affairs prevented him from taking the action, that he contemplated such action within the coming year, and that his mind was somewhat more at ease. The other claimed that he was too deeply committed to make a change for quite some time to come.

Taking action, of course, is only part of the story as far as evaluation of a process is concerned. One can still question the effectiveness of the action in some instances. Here our data are still quite limited, but we do have some. For example, an engineer who changed his job in the same company claimed that he was now happier. Almost simultaneously, both his immediate superior and the president of the company reported, unknown to the engineer himself, that his work effectiveness had improved considerably. It is hoped that a detailed and sophisticated follow up study on the entire sample can be made at a later date.

Conclusions and Implications

1. The typical engineer examined in this study had abilities of important usefulness to American industry, abilities that in many instances were not being used to best advantage.

2. Assuming availability of today's assessment methods, better career guidance at the undergraduate level might have prevented some of the problems presented.

3. Better screening and placement techniques by employers could have enabled better utilization of these people's abilities, and thereby reduced misery and hardship suffered both by company and individual.

4. Technology changes, company vicissitudes, changes within the individual, and other factors can create career crossroads for the experienced engineer, thereby developing the need for periodic self-appraisal as a basis for optimum direction of effort, achievement, and personal happiness. Follow up data suggest that such an appraisal, incorporating the methods discussed in this paper, serve a useful purpose in helping the "midstream engineer" decide whether to stick to his present job, accept an offer, change his field, rectify his limitations, seek further professional assistance, etc.

5. The superior intelligence of the present sample, coupled with its willingness to face problems, may very well make it a highly select one. Conceivably there is a counterpart sample that also needs guidance but doesn't seek it for varied reasons. Such a group may represent a source of considerable technical manpower potential.

THE INDUSTRIAL TECHNOLOGIST AND THE SCIENTIFIC REVOLUTION

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The Scientific Revolution is one of the important ideological forces of this century. In tracing its effects, the relationships between technologists and others in industry are discussed. Examination of stages in the technologist's development furnish background for evaluating firm and individual responses to obsolescence of technical information.

The Scientific Revolution

Systematically applying science to industry on a large scale is a relatively recent phenomenon. During the Industrial Revolution beginning in eighteenth century Britain, "chemistry played only a small part in its earlier phases and biology ... none at all. Electricity remained a toy and even metallurgy was mainly in the hands of practical producers rather than scientists."[1]

This situation prevailed well into the last half of the nineteenth century, when, with great reluctance, the universities began to consider the problems of industry, and, with equally great reluctance, industry began to find useful the formal technical training available in colleges and universities. Before the 1870's in Britain, "training in technology was through apprenticeship on the job; and any formal training in colleges was regarded as likely to lead to the disclosure of know-how and trade secrets."[2] Nevertheless, the growing impact of science on industry sparked a second, more profound development which C. P. Snow has called "The Scientific Revolution".

"Dating the second change is very largely a matter of taste. Some would prefer to go back to the first large-scale chemical or engineering industries about 60 years ago,... I should put it much farther on; not earlier than thirty to forty years ago - the time when atomic particles were first made industrial use of. I believe the industrial society of electronics, atomic energy, automation, is in cardinal respects, different in kind from any that has gone before, and will change the world much more. This transformation is entitled to the name of 'Scientific Revolution'."[3]

In industry, the embodiment of the Scientific Revolution is likely to be the engineer, applied scientist, or mathematician, all of whom can be grouped in the category of "industrial technologist".

With the intensification of the Scientific Revolution, the old craft-oriented ideas in industry have gradually given way to scientifically based ideas. Inexorably, the technologist has been drawn closer to the center of the industrial stage. Out of the small laboratory and design room, he has moved into production, which he now dominates, into marketing, into the front office and onto the front pages of the public press where he is usually known as the "scientist". The technologist's vertical mobility in industry vis-a-vis other groups is the result of his greater ability to interpret underlying technological facts forming the bases for more and more managerial decisions. This vertical mobility is most apparent in industries such as electronics and aerospace undergoing rapid technical change.

Technologist and Non-Technologist

Snow and others have commented at length on the gap between the technologist, or scientist, and the rest of society. Less pronounced in industry where many of the non-scientifically trained specialists have more knowledge of technology and technologists than the general public, the cleavage still exists. In recent years, the cleavage has grown as the technologist has moved into industrial positions formerly pre-empted by other specialists. The latter have developed a number of stereotyped views of technologists which are widely circulated and have become part of the folklore of industry. The accountant knows the technologist as an incapable businessman, the marketing specialist knows him as a boor whose manners antagonize the customer, the contracts manager knows him as the perfectionist who always attempts to do a technical job above and beyond the terms of the contract, the personnel director knows him as a prima donna who takes advantage of his good bargaining position in the market place.[4]

Nor is this concern with the soul of the technologist of recent origin. In 1922, a Committee of the National Personnel Association, the forerunner of the American Management Association, said:

"As engineers constitute an increasingly influential group in modern industry and government, all member companies are concerned that the schools shall ground them in sound principles and equip them with sound methods in their relations to social and economic questions. There is a need that engineers shall attack these questions with the same unprejudiced fact-finding analytical methods as they have used with such marked success on material problems. As a balance to these dispassionate, scientific methods, there is and equal need among engineers for sympathetic insight into human motives and aspirations and an understanding of the principles which underlie governmental, business and industrial organizations."[5]

This statement, written forty years ago at a time when the Scientific Revolution was beginning, seems to reflect fairly accurately the present-day view of the management fraternity toward the engineer or technologist. Recognizing the increased importance of the engineer in industry, the Committe hopes that he will somehow become like other men through an educational process emphasizing the study of business and management.

Through the intervening years, the management and education groups, never quite abandoning the hope that technical schools would increase the non-technical content of their curricula, have attempted with some success to train the technologist by encouraging him to persue formal studies leading toward degrees in business. Also they have provided management seminars and symposia slanted toward technologists.

Outside industry, although the general public admires the technologist's accomplishments, the non-technical thinker tends to resent the emergence of a new type of narrowly specialized leader in society lacking training or interest in humanist values and allegedly caring nothing about philosophy, art, music, literature, languages, or history. The humanist has been less effective than the business or management specialist in presenting a well-defined course of action to cure the shortcomings of this parvenu cast up by the Scientific Revolution.

Well aware that they do not offer great sustenance in the humanities, the technical schools have been unable to allot more than 15 to 20% of their curricula to non-technical courses. They are more concerned with the need to develop technologists whose training in basic science and the "engineering of science"[6] will prove resistant to obsolescence. Industrial management, convinced that training of technologists in management and business benefits the firms, is unconvinced that training in philosophy would have a similar effect. Nevertheless, the humanist can reach the technologist through less formal channels than schools. For the technologist is human, too, and displays interest in the general culture equal to or greater than other specialist groups in industry.

Spurred on at least in part by the critical concern lavished on him, the technologist, after he has achieved a degree of maturity, seeks to combat the narrowness of his viewpoint, both real and imaginary, by entering the Great Books Course, engaging in various community services, or studying music or business administration. Some approach such cultural and social activities as if they are trying to erase the popular image of being creeps. By indulging in such activities, technologists may achieve commendable degrees of versatility, but, in the process, may lose touch with the relentless Scientific Revolution. In broadening his skills, therefore, the technologist who has achieved a position of responsibility in industrial management may have shed his technical coat as an outworn garment. Often the garment is completely threadbare. The pace of the Scientific Revolution assures the obsolescence of knowledge and techniques not revitalized periodically.

Stages Of Maturity

Considerations of the stages of maturity in the professional life of the technologist afford some basis for evaluating his effectiveness in industrial society.

The working lifetime of the technologist can be arbitrarily divided into four ages: childhood, youth, maturity, old-age. These categories have nothing at all to do with chronological age. Rather they have to do with outlook toward and command of technology. Some men run the whole gamut from childhood to senility in a ten-year period. Others retain the outlook of youth after a lifetime of creative work at chronological ages at which many of their colleagues have entered technological maturity or old-age.

Usually, the engineer or scientist entering industry has emerged from school with some understanding of the basic concepts in his chosen field. His information is untried by practical problems, but he is in a position to absorb information quickly in an unfamiliar and sometimes hostile environment, that of industry. Entry into industry thus is the beginning of technological childhood in which the entrant learns very rapidly and deepens his understanding of at least some, possibly narrowly specialized, aspects of technology. After a certain length of time, our technologist is in a position to pump out some of the information he has stored during childhood in the form of new ideas.

Youth is the age of vigor, of bold thinking. Although some technologists never leave this age, most move into the mature phase.

In maturity, the technologist may become either a narrow uncreative specialist or a supervisor of others. In either case, he becomes less involved personally in the solution of novel technical problems. During the mature phase, his knowledge of fields other than his own may develop rapidly. He may be able to categorize problems or frame them far more effectively than he did as a youthful technologist. But his ability to solve problems has deteriorated, and he has begun to lose intimate contact with the Scientific Revolution. The really new or basic concepts he now understands with an uncomfortable superficiality. Because the breadth of his interests may have expanded greatly, he often fails to recognize his growing remoteness from the cutting edge of the state-of-the-art. He is perhaps more adept than ever at grasping the implications of product improvement, but much less perceptive in grasping the significance of new technology. He can fully appreciate the value of the ingenious idea to reduce axle friction on the carriage, but may reject as impractical the automobile.

The mature technologist in industrial management is in a position where his attention is drawn to the activities of non-technical specialists. He becomes aware of the problems of the Sales Manager, the Controller, the Contracts Director. Now he may feel his lack of preparation in the business world and, in setting out to remedy his defects, devotes less and less time to technology.

As some poorly defined boundary, the mat mature technologist crosses over into technological old-age. The individual crossing this boundary may be entering the age of youth in the world of Sales, or of Management, but in the world of technology, his outlook is retrospective, and the Scientific Revolution has passed by him. Often the new vocation of the senile technologist offers an opportunity for honorable withdrawal from the wearisome race against technical obsolescence. Although the senile technologist knows little about current technology, he may be precisely the man on whom rests major responsibility for interpreting the Scientific Revolution for the benefit of the non-technical members of the industrial organization. Thus evolves one of the ironies of modern industry. The Scientific Revolution may have placed one of its own in a seat of power, but on the road to power, he has succeeded in retaining only the image rather than the substance of technical skill.

Responses To Obsolescence Of Technical Knowledge

Many a corporation has thought to have failed or declined because of unsound management, which may take many forms. Of increasing importance in the industries buffeted most severely by technical change is the failure of key members of management to comprehend the scope and direction of the Scientific Revolution as it affects their company in sufficient time to redirect its activities. Frequency the failure of management to keep abreast of current technical developments is the result of relying for technical decisions on the senile technologist or the non-technical members of the management team who underrate effects of technical change.

For the individual firm, the growing importance of the technologist may mean more products and greater opportunities for sales and profits. But it finds itself forced to reduce the conflict between technical and non-technical personnel, and to cope with lack of technical knowledge at the level of general management. At the very least, a tendency toward sluggishness in reacting to technical change may become apparent in the large and medium-sized corporation. What can be done to avoid such sluggishness, potentially destructive to the corporation's well-being? Education is the usual answer. But what kind, and of whom?

The firm lacks interest in long-term solutions, consciously or unconsciously following the Keynesian dictum that in the long-run we are all dead. In the short-run, the firm can expect very few benefits from re-oriented public school and university education programs. It must largely work with the human materials it has. Although many companies have spent large sums on management training for key personnel, few have spent funds on technical training. Most of the technical programs, both in-house and out-of-house, have been directed toward the youthful engineer.[7] Important as these programs may be, they have little immediate effect on the firm's ability to come to grips with rapid technical change because they have little effect on those in the policy making positions--the mature and senile technologists and the non-technical executives.

What is needed is a serious technical education program for senior technologists and, equally important, for the comptrollers, marketing directors, legal counsels, and corporate officials who may have command of their specialties and of management techniques but usually lack both knowledge and interest in technology. The firms interest in training these two groups of executives in technology should be to rejuvenate the mature or senile technologist sufficiently so that he can once more function effectively during a period of great technical change and to give the non-technical executive a better understanding of the world of science and technology so that he may evaluate information on which to base every-day decisions.

Another step the firm may take to avoid the consequences of technical obsolescence or ignorance in management is to maintain better lines of communication between upper management and the youthful technologists who have most of the orignal ideas. Maintaining such lines of communications has implications which can only be touched on here. Finding out who are the youthful technologists -- those with creative ideas -- in a large organization may prove to be a formidable task. As was pointed out above, chronological age is a defective indicator of creativity. Once having determined with which technologists it must maintain contact, management must establish lines of communications with them outside normal channels, a very difficult task for the tightly organized firm.

Turning to the individual technologist, what can he do to approach intelligently the problems of inter-personal conflict and of obsolescence? Conflicts with non-technical personnel can be avoided by eschewing all supervisory roles. The technologist can thus spend all of his time in pursuing technical excellence, if he desires. This is, however, hardly a solution for most individuals.

The attractiveness of the management career and the need for technical strength in management assure the development of many of the more talented technologists along management lines. These technologists must face up to the skill of and conflict with the non-technical world as well as the dangers of obsolescence. Thus, they must attempt to absorb the skills of non-technical management without succumbing to the latter's built-in bias against technical detail. Some attempt must be made to keep in touch with scientific and technical trends through regular study of the literature, technical society participation, and formal schooling. Even if such activities fail to preserve the youth of the technologist, they can serve to prevent ignorance of the state-of-the-art and translation of this ignorance into corporate mismanagement.

The technologist in management will often be forced to make choices between keeping up technically or developing other interests and skills articulate associates and critics insist he needs. He may be forced to adopt negative attitudes toward the conventional wisdom of industrial society. For example, he may find it expedient to consider the management development seminar unfavorably and seriously weigh the value it has to him before agreeing to spend precious time in participating. He must also weight the value of the public relations and customer relations activities he has permitted to consume large blocs of his time. The technologist in industry must keep in mind that he is industry's tie to one of the most dynamic ideological forces man has known and that his ability to contribute as a technologist will be determined in large measure by how well he preserves that tie. All men will not choose to retain it. They may weaken it or cut it as they will, but should know the reasons for their actions and recognize the growing limitations on their ability to interpret the Scientific Revolution in any terms meaningful in industry.

Conclusion

The technologists need a tougher skin and more faith in his own capabilities. He must resign himself to falling far short of meeting the high standard of intellectual versatility expected by his admirers or demanded by his critics. Yet the Scientific Revolution has given him great opportunities in industry as well as great responsibilities. It has given him the power to set his own course and develop his own style not only in technology but in management as well. In return it demans a Lifetime of struggle against obsolescence and a firm rejection of many pleasant activities which divert him from his task.

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PROGRAMMING: THE MECHANIZATION
OF RATIONALITY

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Abstract

Classical rational management techniques reappear in a comparative analysis of economic or system analysis, programmed instruction or teaching machines, computer programming and PERT programming. These techniques, like all management tools, must apply to other management tools and be useful in the practice of management, as well as being applicable to themselves. These mechanistic processes are rational and successful because they force the user to clearly define objectives, plan, carry out functions in an orderly manner and pragmatically demonstrate the appropriateness of the solution. The use of programming techniques on programming techniques is the main example.

LIMITED RESOURCES - A CHALLENGE FOR SPACE-AGE ENGINEERING MANAGERS

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Summary

Though every engineering manager would like to have more men, time, and money than he now has to do his job, he must face up to the fact that such resources will be very limited in this country for the indefinite future. The United States has too many technical programs it must accomplish in limited time with a finite number of dollars to devote anything but minimum possible resources to each program.

This paper states categorically that every engineering manager, from the highest to the lowest levels of technical supervision, is strategically placed and is obligated to multiply the effectiveness of the nation's resources substantially by better planning and managing.

Several examples are given in areas of planning, utilization of proven designs, and engineering organization that indicate some methods by which a company might better utilize its resources in accomplishing its technical programs. These examples are intended primarily to stimulate thinking on a problem of great importance to this nation

Introduction

Achievements in science and technology in the past twenty years have dwarfed all previous accomplishments. The development of atomic and nuclear power, exploration in space, and the increase in speed of travel of man by a factor of at least twenty in this period of time are examples of these achievements. There is nothing to indicate that the rate of technical achievement will decrease in the next twenty years.

It is now generally recognized in this country that this nation has much more at stake in technical progress than the benefits of the achievements themselves. Competition for world-wide leadership is now a part of the total scene; there is no doubt that our role in world leadership is related to the technical (as well as social) progress we make as a nation.

The purpose of this paper is to examine the problem of managing the resources to support our technological problems in all of the areas with which we as engineers are familiar--research, development, and manufacturing programs in fields of materials, parts, components, mechanisms, electronic equipment, subsystems, and systems. Programs in all of these areas require human and material resources. However, the greatest problems arise in marshaling the resources required for subsystem and system development programs. The experience we gain with these programs is applicable in many ways to our research and development programs in the other fields. Furthermore, there is no more difficult field today than that of large subsystem and system management, where so much money is involved and the problems arising from the complexity and sheer magnitude of the system are unmatched. Our aerospace, atomic and nuclear power, data processing, and many other programs fall in this category. Variations of these programs on a smaller scale exist by the thousands and are absorbing a tremendous amount of the nation's resources.

An additional serious problem is presented by the rapid pace of technical progress--the problem of technical obsolescence, or, in other words, the need to develop an equipment or system rapidly enough for it to be still useful when it is released for service. This explains why most technical programs with which we are familiar are fast-moving ones, often under considerable pressure to meet tight schedules. Many programs today are not scheduled for minimum development costs but rather, are scheduled for minimum total cost, taking into account the cost and pay-off of the operational systems in service. Normally, this means that schedules are compressed from what they would be for achieving minimum development costs, because the customer is willing to pay more for more rapid development of the system in order that it may go into service and perform usefully before it becomes obsolescent. This problem has been recognized by the Defense Department, and strong emphasis is being placed on the R&D phase of the program, not committing follow-on procurement without considerable assurance that the equipment or system is feasible and that it will not be obsolescent by the time it is developed. Program emphasis on R&D conflicts with the so-called "principle of concurrency" by which operational procurement is committed concurrently with development, but obviously this is a practice that should be followed only for extremely urgent and vital national programs, and where the probability of going up a blind alley is low.

It is evident that in seeking to make the most progress with limited resources, it is extremely important to choose worth-while programs, and it is this consideration that occupies so much of the time and attention of program planners in Washington and elsewhere. The nation loses when it commits precious resources to programs of little or no value.

The problem of managing our resources to accomplish the technical programs that are selected is in the hands of the nation's scientific and engineering managers. It is our job to guide the human and physical resources effectively in accomplishing the objectives of our technical programs. Now, every manager likes to have more than enough men, time, and money to do his job. It is pretty generally recognized that men (especially technically trained men) and time are in short supply, and although some may believe that money is readily manufactured, it is a fact that with present U. S. budgets, there is not enough money for all of the space and other projects we would like to do. It is a question as to which of these--men, time, or money--is the fundamental limitation to our technical programs as a whole, but there is ample evidence to show that all three are playing a part in slowing the pace of progress. This definitely is a problem for the nation - it goes far beyond the boundaries of your company or mine.

The fastest way to increase the effectiveness and pace of our nation's technical programs is not to ask for more time, more people, or more money--but to manage them better. This is the way to go further per hour or per person or per dollar. When I speak of management here, I am considering it in its total sense--not only the technique of planning, organization, control, etc., but also such important factors in team operations as the human relationships, communications, etc. We engineering managers can learn much from managers in other fields about these matters. It is not my intent here to cover the broad area of management, but merely to discuss an example or two from our own experience that may suggest some avenues that might be followed in improving our performance as engineering managers.

This takes imagination - intelligence - flexibility - and innovation. People, including engineering managers, resist change. But these are days of new technologies and new objectives - and new methods must be developed to meet the needs of our programs. Many of us still think in terms of World War II (17 years ago), old technologies, and old ways of doing things. Senior managers are especially susceptible to this disease.

The noted historian, Arnold Toynbee, in his examination of many of the world's civilizations, concluded that all of the ones that had died or were in their death throes had one common weakness--the drying up of creative leadership. The failures resulted from a weakening of the will to meet new difficulties and from attempts to solve present problems with old solutions that did not meet present needs.

In many respects, the engineering manager is faced with the challenge that presented itself to these ancient and modern civilizations. In particular, the challenge of technical achievement with limited resources faces all of us. This is the problem: How shall we do a better job of achieving technical objectives with the limited resources at our disposal? Let us consider several areas where some improvements can perhaps be made.

Better Planning

In my judgment the technique most overlooked in management is planning. This holds true whether one is talking of long-range planning for a business, or the planning of a research project, or the planning of a large systems project. Most of us apparently cannot wait to begin doing something, be it experimentation, requisitioning manpower, or spending money in some other rapid and perhaps haphazard manner. One would think that our technical training would stand us in good stead when it came to planning, but it seems to be a rare program that has adequate overall system design, component design, proper planning of costs, sufficient detail in scheduling, and so on. In the area of development, especially, history is replete with examples of programs that got off to a flying start and never crossed the finish line because of poor or inadequate planning. There is an office in the Navy Department in Washington where this plaintive question has been tacked to the wall (Figure 1):

Why is there never enough time to do it right
but
always enough time to do it over?

The first rule of any activity or program should be to determine or define its objective. It has been well said that unless a person knows where he is going, any road will take him there. With the objective clearly defined, it then becomes practical to define how - where - when, and the other elements required to accomplish the objective. Probably the most important consideration in a systems program is the systems design phase. We could save many man-hours and money by better system design. For instance, there is a fair amount of evidence to indicate that adequate consideration is often not given to the tolerance problem in designing systems and components. At the present time, devices exist by which simple circuits can be checked component-by-component experimentally and rapidly by means of digital programming techniques.* Mathematical representations of circuits can also be used to evaluate the effects of time and environment. Analog and digital computer techniques can then be used early in the system design and analysis. Such simulation methods in system design provide substantial improvement in the potential

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* K. Packard, M. Goldstein, N. Stone, and J. Cavallari, "Electronic Circuit Tolerances," WESCON Convention Record - Reliability & Quality Control, 19 August 1959.

reliability of the system and represents potential savings in every area from development to logistics in the field. Simulation is being applied to some extent; it should be applied more.

New tools of management exist in the form of critical-path methods, one of which is PERT (Program Evaluation Review Technique). Probably the greatest value of such a technique is not in controlling or analyzing a program, but in forcing proper planning, in the beginning, of the steps required to achieve the objective. Such events are then placed on a time scale to arrive at an overall plan of events that must take place at certain times in order to achieve the objective at the desired time. Planning in this depth can be quite revealing--and disturbing. Our first PERT exercise showed a potential program slippage of 1-1/2 years. We finally got this down to approximately three months, but the exercise graphically revealed the usefulness of a critical-path technique in program planning. Various refinements of the basic technique are constantly being suggested, and most are better aids to planning.*

It is probable that the Air Force and other customers of large system programs will require PERT or similar techniques in the future. The result will certainly be a better utilization of limited resources for the program so planned.

More Effective Utilization of Good Engineering Designs

Since most engineering managers are at least partially engineers (perhaps by memory only), it is sometimes not easy to be objective about engineering designs that exist. Almost any engineer can think of interesting ways that a design might be improved or a totally new one evolved. On the other hand, an existing design using proven components will often prove to be adequate - and perhaps superior to a new design using the same class of components. This is especially true for standard types of circuits: power supplies, audio, video, and IF amplifiers, basic digital circuitry, modulators, local oscillators, etc. It is certain we are not making the most effective use of good, approved, and proven designs. By not doing so, we are repeating design work unnecessarily, wasting man-hours and money--in short, not making maximum use of our limited resources. We would be more effective if our limited technical manpower were pioneering on advanced developments rather than covering ground already well-ploughed.

Conscious of this problem, we have made several surveys at Airborne Instruments Laboratory (AIL). Figure 2 shows the results of the first survey, in which we studied the relative frequency with which nine different engineering groups within AIL used 10 typical electronic circuits. Some duplication and repetition of development are known to have occurred, especially by groups with high (H) use of the same type circuit. The figure suggests that use of common designs could release design manpower, and save time and money.

Figure 3 shows the result of a second survey on power supplies for one major program. The number of different types specified (187) is particularly impressive. Some are known to be similar. Better standardization would have reduced the number of types required.

There are effective ways by which engineering managers can encourage the use of proven and acceptable designs by our technical staffs. One way is to make use of the work of a good reliability group. First, this group can prepare a manual of qualified parts for use by designers. This manual is kept up-to-date, and additions are made frequently. Second, circuits of good design using qualified parts are evaluated in design reviews and thoroughly tested. These can be then released for general use by means of a qualified circuits manual, which is maintained in the same manner as the qualified parts manual. Finally, when modules are built, reviewed, tested, and approved, a qualified modules manual can be issued to encourage the use of standard qualified modules. This has been particularly effective with digital modules at AIL.

The problem of obsolescence always overhangs a program of this type. To be effective the data must be timely. As new parts, circuits, and modules are qualified and released, the appropriate information must rapidly find its way to the design engineers.

It is also worth noting in this connection that the Department of Defense, as well as the several Services, have programs of standard circuits etc., including micro-electronic standards. There are problems associated with these programs (particularly the problem of timeliness), but they are worthy of greater industry support.

Organization as a Tool of the Engineering Manager

The purpose of organization in any group is to effectively match the people, facilities, and resources of the group to the tasks that need to be done. Changing tasks, people, and resources require changes in organization for optimum performance. Thus the effective organization is very likely a flexible one.

Many technical programs today, particularly for space, are radically different from those of 10, and even 5, years ago. Programs today are fewer in number but larger in size. Many space programs and some nonspace programs never expect to see a production phase. A few years ago models and designs were released by engineering departments; then the production people took over and

* For example, see: Howard Eisner, "A Generalized Network Approach to the Planning and Scheduling of a Research Project," Operations Research, Volume 10, Number 1, pages 115 through 125, January-February, 1962.

manufactured the deliverable items, generally in quantity. Often designs were reworked by the production engineers to suit their notions and practices. Now the engineering team on a large program may run the job from breadboard to blastoff. The engineering design release is the final release. People and practices across the company must be coordinated to work together effectively as a team. New team members may include reliability and quality control groups.

The large systems programs especially have required a great deal of thought as to the proper organization of the effort within a company. In general, two basic concepts of organization have been developed: (1) the task- or project-oriented organization, sometimes called a task force, and (2) the program management concept, which is functionally oriented. In the task-oriented organization, the task or work is essentially kept as a unit, and people from various portions of the company are "moved in" to form a task force led by a leader, the common goal being the accomplishment of the specific task. In the functionally oriented organization, the task is split up into manageable portions, which are assigned to functional groups who operate as usual. This form of operation calls for much more care in dividing, describing, assigning, and controlling the work. Obviously, the problem of personal relationships across department or division interfaces is more difficult than in the task-oriented organization.

It is unusual to have an organization that is clearly of one form or the other. Usually, the organization, though predominantly of one form, contains elements of both forms of organization. The best organization is obviously a function of the requirments of the particular program, the basic organization of the company, the people themselves and the organizational relationships to which they are accustomed, and other factors. It is highly unlikely that the organization of any company can remain fixed for a very long period if the company is engaged in subsystem or system programs. As a matter of fact, if the organization of the company, or at least major parts of it, remain fixed for more than a year in this era of technological activity, it is possible that the company is not adapting to a changing environment--and very likely is not making the most of its resources.

The evolution of an organization at AIL that attempted to keep pace with its responsibilities is shown in Figures 4 through 7. Note the evolution of program management teams, an engineering operations support group (finally merged with the manufacturing division), and reliability and quality control groups.

One thing is quite certain about the last organization shown; improvements will continue to be made, both in its composition and in its way of operation. The challenge to the engineering managers on that chart are to make the organization work well and to seek, day in and day out, to make it work better as a means for utilizing most effectively the resources at their command to accomplish the programs assigned to them.

A further word or two might be said about the relative advantages and disadvantages of the task-oriented organization versus the program management organization. Where one project only is being considered, it probably does not make much difference which organization is used--though the task-oriented organization would probably be favored by most managers in the belief that it would be more efficient. Such an organization also requires fewer highly qualified personnel, since a few good leaders at the top can essentially direct the program. Where several projects are under way, it appears more efficient to use program management organizations because relatively few functional specialists can service several projects. Further, in most companies, higher morale will prevail when people are not shuffled around as much as they would be if each new project required the creation of a new task-oriented organization. However, the best organizations (as stated before) depend on several factors that vary from company to company and program to program. It is up to each company to be extremely sensitive to its organization problems if its programs are to be accomplished most effectively.

Conclusion

Our country is in a serious competition. We must obtain the most return for the resources invested. In order to do this, the programs to be pursued must be carefully selected. After they are selected, however, the responsibility for optimizing return on specific programs is directly the responsibility of the engineering manager. Old-fashioned approaches must be examined and revised courageously where necessary. To meet their responsibility, engineering managers must pay especial attention to:

1. Better planning--which includes sound statement of objectives and wise delineation of the tools and methods to be used in accomplishing the objective,
2. Avoidance of duplication through appropriate standardization, providing returns through lowered cost and better reliability,
3. Careful design of an organization that will optimize performance through control not only of tangible items such as lines of communication and authority but also of the intangible sociological factors that are important to the people who, in the final analysis, are the heart and life of the effort.

Acknowledgment

Grateful acknowledgment is made of the helpful comments and suggestions received from W. B. Offutt, K. Packard, and J. G. Stephenson of Airborne Instruments Laboratory.

WHY IS THERE
NEVER ENOUGH TIME TO
DO IT RIGHT
BUT
ALWAYS ENOUGH TIME TO
DO IT OVER?

Fig. 1

ELECTRONIC CIRCUIT TYPE	ENGINEERING GROUP								
	1	2	3	4	5	6	7	8	9
BINARY FLIP-FLOP	(H)				(H)			(H)	(H)
BLOCKING OSCILLATOR								(H)	(H)
DIODE LOGIC					M			M	M
DIGITAL MODULES		(H)		L		M	(H)		(H)
AMPLIFIER (INVERTER)	M				L				M
EMITTER FOLLOWER	(H)				M			M	M
VIDEO AMPLIFIER	L		(H)		L		L	M	L
IF AMPLIFIER	L	M	(H)				(H)	L	L
REGULATED POWER SUPPLY		M	M	L	L		(H)		L
AUDIO AMPLIFIER		(H)					M		

CODE: L = LOW USAGE
M = MEDIUM USAGE
H = HIGH USAGE

Fig. 2. Usage of circuit types within AIL.

POWER-SUPPLY TYPES SPECIFIED	187
TOTAL NUMBER OF UNITS REQUIRED	573
NUMBER OF SOURCES USED (INCLUDES IN-HOUSE)	26

Fig. 3. Survey of power supply requirements on a major program.

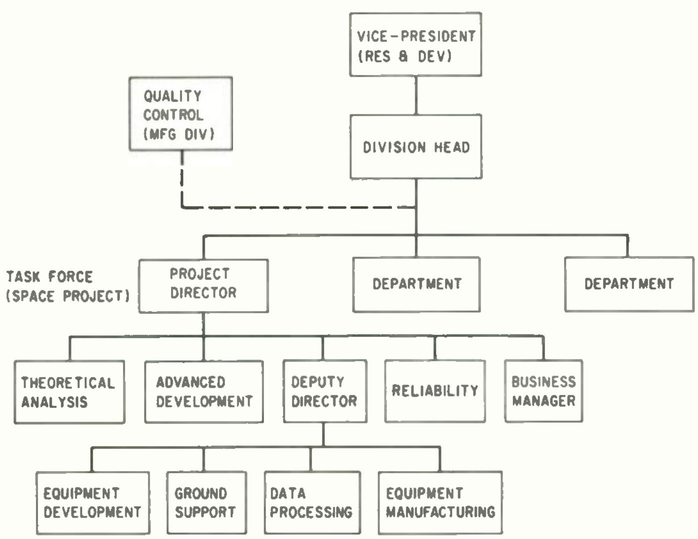

Fig. 4. Task-oriented organization.

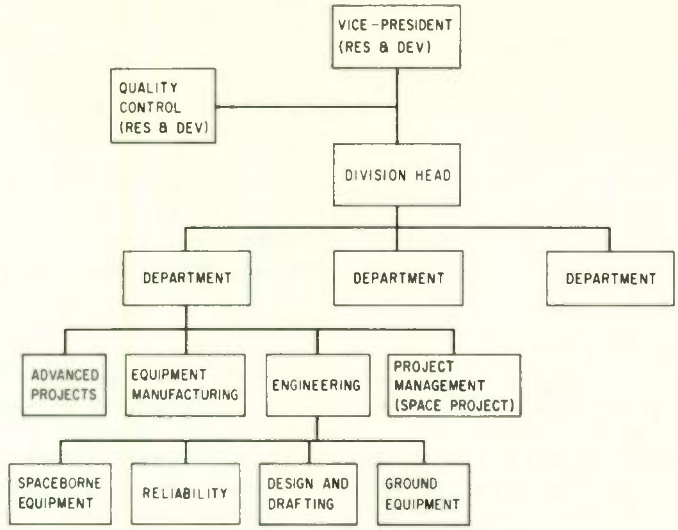

Fig. 5. Functionally oriented organization.

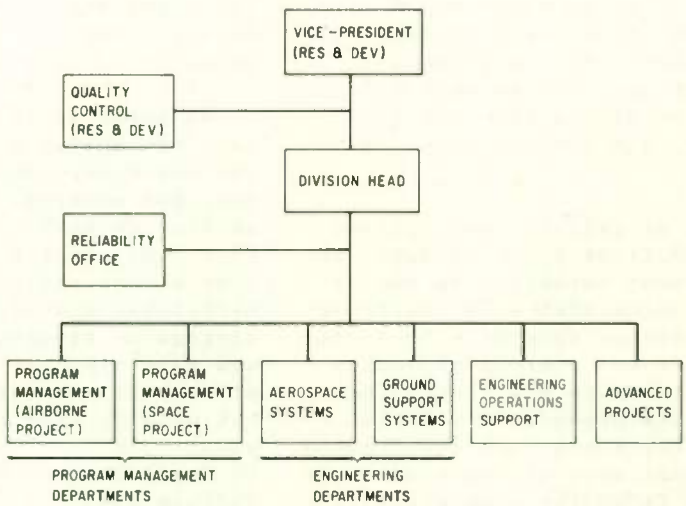

Fig. 6. Functional division organization (step 1).

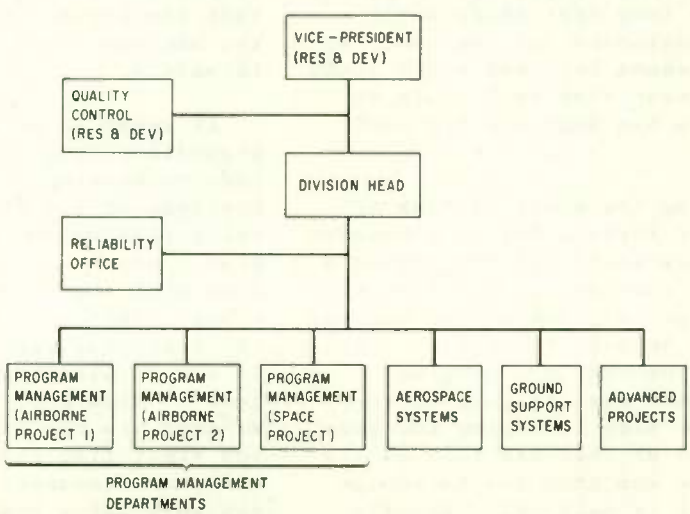

Fig. 7. Functional division organization (step 2).

FINANCING A NEW SPACE AGE COMPANY

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One of the most difficult things about presenting a paper on this subject is to avoid the temptation to preach. To remember that it is being presented with 20/20 hindsight and not to underrate the power of enthusiasm. It is very easy to tell someone about the things you did right during a difficult navigation period and gloss over your mistakes which could have swamped the ship. It is easy to say I did this and we did that and therefore you should do thus and so. It is more difficult to say why we did so and what the alternatives were and let you draw your own conclusions.

It took a lot of gall for us to offer this paper in the first place because, in so doing, we present ourselves as having been singularly successful when really we should say we listened carefully to a good board of directors and a group of qualified advisors. I assure you though that the purpose of this presentation is to pass on some of the ideas that have rubbed off during our past several years of association with the financial community. I am sure there are many others who could take my place and do a better job. The difference is -- they kept their mouth shut while I volunteered for the job. My wife has a sign above her desk which reads "There's many a poor fish that would be alive today if he had kept his big mouth shut."

I enjoy reading the short stories of enterprise in the Fortune Magazine because they almost always start off describing a man with an idea who had a rough time at first but began getting customers, capital and people until he made the grade. All too frequently, however, the original founder or idea man was not part of the enterprise by the time it became successful. He had sold or lost his idea or his company to others who knew how to manage their money until it paid off. Usually the enterprise was started by two people, one the doer and the other the salesman. Often there was a third man - the financier. A common factor seems to be a 50/50 ownership and initial investment when two-man teams are involved or a 1/3 ownership for each when three are involved and the financial man puts up the capital but takes no direct part in company operation. You might find it worth your time to browse through several years of Fortune Magazine looking at these stories.

My point is this. Before you take off in a new business, spend some time finding out how others made the grade. Not just one, but several. You will find out who starts new companies, why they start and what they start with. You will see that they always started with an idea that was marketable and either put in their own savings or brought in a partner with money and gave him part of the business. Some of them started with a few hundred dollars but usually they scraped up several thousand. And very frequently they lost most of it during the first year. Naturally, Fortune does not tell about the ones who went out of business at that time, but it does tell of some who got more money but lost the business to the new investors. The success story is about the new investors.

It seems to me that the most important ingredient is knowing what to do with your idea -- knowing why you want to go into a business in the first place -- and then being willing to sit down and develop a plan. Write it out - think about it - set down what can happen if you have guessed wrong. Then assume that you are half right and plan your finances on that basis. This is a good place to call in a friend who is good at figures. One who has obviously managed his own finances successfully. Or you might find someone who has retired after a successful business career to help you work out a financial plan. If I can offer any advice at all it is to temper your plans in accordance with the money you or your associates have or can borrow. If you do bring someone into the group who is willing to put up the money, be sure you know him well and that he knows you. Then, by all means, agree then and there on how much of the business he will own and what additional money he may be willing and able to invest and under what conditions. Make written agreements and have them finalized by an attorney. This is extremely important, even among friends because at the outset each person sees something for himself in a successful venture that is worth either time or money. Each person is speculating on the future based on assumptions that are made today. An agreement reached at this stage and reduced to writing can become the basis for a successful venture. A disagreement at a later date which depends on memory of original intent can wreck the enterprise and good friendships.

At this point you should consider the pros and cons of operating as a partnership or a corporation. In a partnership the prime disadvantage is the unlimited personal liability for business losses plus the potential liability for the acts of the other partners. Your personal assets such as your home, for example, could be placed in jeopardy. A corporation offers limited liability; that is, you are not liable beyond the amount of capital stock owned. From a tax viewpoint there is little difference for most small business organizations. This is because under the 1954 Code a small business corporation can elect to be taxed as a partnership. Personally, I think that the corporate form is preferable particularly if the ultimate goal is to go to the public for additional financing. If you do incorporate, you need to consider how you tie up your money. Do you put it all into the corporation and take stock in exchange? Or do you put part of it in for stock and lend the rest? If you are successful and want your initial investment back, it will be taxed as a dividend by the first method. If you loan it, you can get it back some time later when the company doesn't need it with no tax obligation except on the accumulated interest. In any event, during this initial hike into your own business, a respected attorney and a good tax man should be your constant companions.

By now you have passed the formalities of organizing your business and have a bank account. Please don't go out and blow your bank account on machinery and equipment. Make arrangements to rent or lease what you need so you can use your money to buy supplies and services which hopefully will go into the product you will sell. This advice may seem so obvious that you wonder why I emphasize it. You would be surprised at how many people don't take it. They will argue that outright purchase is cheaper than renting and that they will always need the gadget to do business. What they forget is that renting or leasing brings other people's money into their business without obligation beyond the return of the device itself. Their ownership in the business is not diluted by a premature need for more money. Hoarding or stretching this initial capital will be as important as successfully building the gadget or marketing the service for which the business was started.

The chances are very good that you have no more money to invest. If you need more before you develop accounts receivable you will very likely have to sell some more of your business to get it. What you really need is to get into a position where you can borrow money, not sell pieces of your company. To do this you need to look like a good business manager who doesn't need money, then shop around for a good banker who will appreciate that you could make out on what you have but can do better if you have more money to operate on. He has money that he wants to put to work, in fact his job depends on it, but he must know that you can earn a profit in your business by using his money. Eventually you will reach the limit of your borrowing capacity. A rough rule is that your borrowing capacity will not exceed your working capital, i.e., the difference between your readily saleable assets and your current or short terms payables. This is another reason for keeping your money available and not tying it up in fixed equipment.

While this is a discussion of new space age financing, please do not neglect your books and records. From the very beginning you must keep informed of your progress by accurate accounting reports. Your confidence in these records will rub off on your banker and others who, after all, will loan or invest, not on your good looks, but on sound basic facts and principles.

The time will come when you need more operating capital than you can save or borrow. Then you must seek outside investors. But what will they want in return for their money? Your first job will be to find out what your business is worth now and what it will probably be worth a few years from now. This is a job for an expert. You may wish to apply rules of thumb such as 20 to 50 or more times earnings but this may not be a good measure if your earnings haven't materialized. An interesting figure that is sometimes employed in electronics is $10,000 per employee, another is your annual business volume. Once you have established a ball park, you are in a position to bargain with investors. But who and how? If you go after private investors, you should know a little about the SEC rules and make certain you don't end up with a technical public offering. And also, you should make certain these investors are really investors who are willing to leave their money for a year or two and not turn around and resell for a quick profit.

Right here you could do well to contact several of the Small Business Investment Corporations and invite them in to look you over. If you are solid, they will be interested. Don't stop with just one but talk to several. Some may not have money to invest in your business. On the other hand, you may be just the thing for another and be able to work out a good deal. In any event you will get an analysis of your business and lots of advice about what you should do. You should have your banker or your financial counsel make the contacts and sit in on your conferences.

You may find that your best course is to sell common stock to private investors because they become part owners in the business and share its profits and risks along with you from then on. Some may want to lend you their money with an option to convert it into common stock later on. Naturally, you will set the conversion price at a higher figure than you would be willing to sell at today. If you have a lot of confidence about your future you will give up less equity this way but if things should get worse, you might have to sell everything to pay off the notes.

The Small Business Investment Corporations are recent aids to small business authorized by Congress. An investment minded group may get an SBIC charter by meeting certain criteria. This gives them an opportunity to borrow money from the SBA on a matching dollar basis provided they invest in small business ventures under certain rules. The Internal Revenue Service allows such investors to write off any losses they suffer against ordinary income but consider any gain as a capital gain. Corporate tax rules do not apply so there is no tax on dividends. The many SBIC's that have been chartered indicates the potential advantage to investors.

You must clearly understand how they operate. They may make straight loans but if they do, they must be for a minimum of five years. Most SBIC's do not wish to do this. They prefer debentures convertible to stock. This means that they loan you the money all right and you have an obligation to pay it back. However, they also agree, and you do too, to exchange the whole of the loan for an agreed on percentage of your company (it must be less than 50%), at their discretion and prior to some fixed date in the future. They are not required to convert but they have the privilege of doing so simply by saying they so elect. You may force the conversion or withdrawal at any time by offering to pay the debt.

Interest rates may be nominal for this kind of investment, possibly 8%, but this may not be all of the cost. You may find that mandatory management advisory services and other hidden costs will add several more points. You may or may not need these services. You should know what you are getting and its true cost.

With so many SBIC's competing with each other today, you should be able to find one who will meet your needs and at a price you can afford to pay. You may have to shop around to find the right one.

Eventually your need for capital will go beyond the private investor or SBIC and you will need help from the institutional investor or even the public investor.

Public stock offering should be the third step. To be undertaken after personal investment capacity has been exhausted. (Personal investment can be interpreted as your own and possibly the funds of a few close friends or associates who know you and your business well.) And after intermediate investors, such as a small business investment company or a small group of sophisticated investors, and, yes, the banks have done all they can for you.

We mention the banks in this review because they have a place that is often overlooked. You will always need credit no matter how large or successful your business - and credit must be established slowly. By starting with small borrowings and making prompt repayments followed by larger borrowings, you establish a reputation with the most important link to the financial community. And besides, by proper banking and financial management, you can almost double your working capital.

While you are doing these things and looking forward to the day when you will sell part of your company to the public in order to have even more working capital, you should familiarize yourself with the steps you will take and the responsibilities you will assume on the public financing route.

The Securities and Exchange Commission, operating under the Securities and Exchange Act of 1934 has a responsibility to protect the investing public from unscrupulous promoters -- and you are a potentially unscrupulous promoter. So you must plan your acts carefully to avoid such a tag. Planning starts now -- when you are inviting private investors to participate. It is so easy to unwittingly become involved in what may be technically termed a public offering and not even know it. The SEC defines a private investor as one who is competent to judge you and your business and knows it well enough to do so. And they frown on too many such investors. They won't put an upper limit on the number, but competent advisors will suggest that it not exceed 20 to 25 people. These investors must not be speculators. The SEC believes that an investor must be willing to invest for one to three years--preferably the latter. It is your responsibility to see that potential investors know these facts about private investment. For your future protection you should get an investment letter from each one stating that they are making an investment and that they do understand what they are doing. If they should change their minds later on or be tempted to sell prematurely because of a high price, the burden of proof of investment is on them and not you or your company.

The SEC allows you to sell stock to the public under one of three general categories.

You may sell less than $50,000 without registration under a Regulation A Exemption, however, you must file a statement with SEC and get a "no objection" letter to do so. You are not required to make any special revelation to your prospective stockholders, although they are free to go to SEC and look over the statement you filed.

If your offering is more than $50,000 but less than $300,000, it still qualifies for a Regulation A Exemption and is known as a small offering. Such an offering requires the filing of a statement with SEC and the distribution of an offering circular to prospective buyers. The SEC must clear your statement and present "no objection" which is tantamount to giving their consent to your offering. Theoretically, the SEC does not scrutinize a Regulation A Exemption as carefully as a regular issue and less delay is encountered in getting their approval. It is paramount, however, for you to avail yourself of the services of a competent attorney who is familiar with the current SEC practices to appreciate any of the savings attributed to this exemption.

For issues greater than $300,000, you must make a full disclosure to SEC, have your stock registered and issue a carefully prepared and fully approved prospectus. If you have any financial skeletons in your closet, they must be brought out and fully disclosed.

Whereas you might get by without an underwriter on a "Regulation A issue," and even then it is a questionable practice, you should, by all means, get an underwriter for a regular issue.

Our advice is to seek a good underwriter when you first think of any kind of public offering. You should conscientiously make an effort to get acquainted with several of them. If you have made a good bank connection, let your banker help you select one. The underwriter may not be interested in your small offering but he can help you in many ways. He will be interested in watching you grow to a size that will justify his services. And you will profit from the association even though you never actually use his services. Most underwriters have staff men whose job it is to seek out and cultivate small growing companies. You can judge the underwriter by the care with which he investigates you, your company and associates. You should encourage such investigations and not be satisfied until you are certain that the underwriter knows your company and its prospects very well.

Then when it comes time to work out an underwriting agreement, you should have a pretty good idea what your company is worth. The underwriter will naturally want to make it on the high side. Setting a price on your company is no job for an amateur. Unless you have had lots of experience or are unusually competent, you should retain independent counsel for your side. Your prospective underwriter will respect you for it and you will have more confidence when an agreement has been reached that it is a fair and equitable price.

Then go to work with your underwriter, his attorneys and your counsel and put together an honest and complete disclosure of your business and your plans.

Since everything might not go as easy as we have outlined, you may want to consider the following suggestions and comments:

The best underwriting agreement is a firm commitment to buy your entire issue at an agreed price as soon as an SEC registration becomes effective.

A "Best Efforts" underwriting is not so good. It suggests either that the underwriter thinks your price is too high or he lacks confidence in the public acceptance of your company.

An "All or Nothing" commitment is in the same category as the "Best Efforts." It suggests that the underwriter doesn't know what the market will do and doesn't want to be saddled with an unsuccessful issue.

The underwriting commission and other costs shouldn't be out of line with similar issues handled by reputable firms in the area. A high commission may signal a wariness on the part of the underwriter but a willingness to stretch a point if the return is high. A reasonable commission is an indication of confidence.

Your underwriter should agree to place your stock in a wide market and avoid a small number of large purchases. This will insure trading of your stock and a market price that is set by a reasonable turnover. He should also agree to participate actively in trading your stock to maintain an orderly market.

You probably can't avoid a certain amount of speculation in your stock which will cause the price to fluctuate rapidly for a short time after the issue. Your underwriter should agree to do what he can to prevent such speculation.

Once you have filed your registration statement with SEC, you must almost go into a publicity seclusion to avoid making statements or generating publicity which will affect the public demand for your stock. The SEC is especially sensitive to so-called "Hot Issues" where the public demand exceeds the supply and the price rises drastically immediately after the issue. Space Age issues have been especially sought by the public until very recently because there have been so many street stories of rapid gains in a short time. Your only salvation is to be extremely careful of what you say, otherwise you run a chance of being considered a promoter.

Be particularly careful of the statements which you include in your registration statement. They must be correct and unchallengeable. Your Board and principal officers assume personal responsibility for these statements as well as any omissions. Don't take any chances, no matter how uncomplimentary they may appear in print. These statements and the fact that they are in the public record may be your only defense later when some irate stockholder who has bought when he shouldn't is accusing you of all kinds of unsavory actions.

Then with the confidence that you have been both legally and morally honest, you can watch with amazement as the public puts their own price tag on your company. It may be much higher than your figure or it may be lower. In any event, you can do little by worrying about it. You should realize that you had competent advice by people who had access to the facts when the price was set. Your job is to make your company meet the growth and profit goals you have already established. Then you will have an honest and sincere answer for your stockholders.

EDUCATING ENGINEERS TO WRITE EFFECTIVELY

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Summary

This paper deals with a vital and integral part of the engineer's professional life--the effective communication of technical information through the written word. This part of the engineer's professional development requires a coordinated effort on the part of the engineer, his employer, and our colleges and universities. This discussion examines four aspects of educating engineers, as follows:

1. The steps the engineer can take to improve his ability as a communicator of technical information.

2. The contributions that industry and our colleges and universities can make to help the engineer in this part of his professional development.

3. The programs available to engineers in the Detroit area.

4. The approach used at two Detroit-area universities in teaching engineers to write.

The Role of the Engineer

Improving the quality and effectiveness of his writing should be an integral part of the engineer's professional development program--a program of continuing self-development that begins when the engineer receives his degree and lasts throughout his professional life. Just as he tries to keep abreast of the technical aspects of his profession, so should the engineer strive to improve his skills as a communicator. Today's engineer cannot afford to write or speak ineffectively. There is little room or time for the inarticulate in our world of computers, missiles, and spacecraft.

Despite the popular belief to the contrary, I believe that engineers can write. They are admirably equipped by their technical training to become excellent communicators of technical information. Many engineers write very well, indeed. Others do not. Their failure to write well, however, does not result from a lack of ability but rather from a lack of knowledge of the techniques that produce clear, forceful prose. I have yet to meet an engineer who, when motivated by the desire to learn, cannot be taught to express his thoughts clearly and logically. If he is willing to work hard, even the poorest writer can learn to construct clear sentences and logical paragraphs. He can be taught to describe equipment, to write clear instructions, to explain an idea, a theory, or a process so that his intended readers can understand and act upon what he is saying. If he can do these things, he can write effectively.

Assuming that an engineer recognizes that he writes poorly, wants to improve his writing, and is willing to invest his time and energy, what steps can he take to further this part of his professional development?

1. He can enroll in adult-education courses offered by local universities.

2. He can participate in company-sponsored courses if they are available.

3. He can embark on a program of self-tutoring.

4. He can become active in groups like the Professional Group on Engineering Writing and Speech (PGEWS) of IRE, or the Society of Technical Writers and Publishers.

The First Step

From my experience as a writer, editor, and teacher, I recommend the college-level, adult-education courses as the first step. These courses, at least as they are presented in the Detroit area, provide a broad background in technical composition and the techniques of presentation. They are not oriented to the specific publications of a given company. In such courses, the student is stimulated by group interaction. His classmates have a wide range of interests; they come from many industries. By exposure to the ideas and needs of persons who work in all phases of engineering from research and development to manufacturing to sales, the student learns to apply different techniques to his problems.

The Second Step

As the second step, a company-sponsored course in report writing, proposal writing, etc., would be helpful. Such a course would probably be oriented to the requirements of the employer. From the employer's viewpoint, such courses could be desirable in that they would help achieve uniformity of style and format. Further, it is possible to concentrate on the types of document used by the company so that the student learns a great deal about writing one or two specific types of technical documents.

In my experience, company-sponsored courses tend to be limited in scope, sometimes almost to the point of becoming inbred. The engineer may learn to organize and write an excellent progress report but find himself unprepared to attempt a proposal or a sales brochure.

Another drawback to this type of course is poor attendance. All too often, the engineer's daily work is allowed to take precedence over courses taught by staff personnel. For maximum results, management must support on-the-job training programs all the way.

The Third Step

To be worthwhile, the third step, self-tutoring, must follow some previous training. Otherwise the student may find himself in the position of a physician attempting to diagnose a disease when he doesn't know what the patient's symptoms are.

To teach oneself to write without a planned program and the criticism and coaching of an instructor, seems to be an almost hopeless task.

However, self-tutoring following a course in technical writing is an excellent way for the engineer to continue to improve his writing throughout his career. There are many excellent textbooks available on various aspects of technical writing, and many technical journals publish articles on the subject. Also, the engineer who has had some previous training can learn from analyzing and evaluating the writing of others as he studies the literature of his own technical specialty.

The Fourth Step

The fourth step in the engineer's professional development program is to participate actively in organizations like PGEWS and STWP. Membership in groups such as these will help him keep in touch with new techniques of presentation. Here, too, he will find the stimulation of working with others as they strive for a better way to communicate their ideas to their colleagues, their employers, and the lay public.

The Role of Industry and Universities

Industry

So far I have spoken of what the engineer can do to help himself. Now I would like to discuss what industry and the universities can do to help the engineer.

Industry has a big stake in helping the engineer to communicate well. That industry is aware of this is evidenced by the fact that we are here today. So to start, we can say that industry can help the engineer to become a better communicator by making it possible for him to attend meetings such as this.

In addition, industry can help the engineer financially by paying all or part of his tuition when he satisfactorily completes a course in technical writing. Industry can also present courses in technical writing to its engineers on company premises during or after business hours. Further, industry can encourage its technical writers and editors to work closely with the engineers in producing reports, proposals, and other publications.

One of the most important steps industrial management can take is to recognize that producing a high-quality technical document takes time and thus schedule the production of a report, proposal, or brochure as carefully and as realistically as they schedule the production of an automobile, an airplane, or an office machine.

The Universities

What can our universities and colleges do? First, in the undergraduate part of an engineer's education, the university should treat the writing part of the engineer's job as seriously as it treats the use of the slide rule, engineering drawing, and higher mathematics.

The causes of the poor quality of writing in business and industry today are many, however, and go much deeper than the lack of training at the college level. Since we are concerned here with the writing of the engineer after he is employed, let us consider what the universities can do to help the graduate engineer. Here, I believe the universities, through their adult-education departments, can provide a real service by cooperating closely with industry, engineering societies, and individual engineers to develop meaningful adult-education courses in technical writing and related subjects. Further, our colleges and universities can help by co-sponsoring symposiums and institutes similar to the PGEWS symposium held at Michigan State University last fall. Some colleges and universities are doing this already. We need more.

Programs in the Detroit Area

So far I have spoken rather generally about educating engineers to write effectively. Now I would like to get specific and tell you something of the opportunities offered in the Detroit area to engineers and others who wish to learn to communicate technical information effectively.

College-Level Adult-Education Courses

First are the adult-education courses offered by our local universities. Here I should like to emphasize that these courses are designed primarily for practicing engineers, although they are also attended by persons wishing to prepare themselves for careers as technical writers. These courses are helpful, and even necessary, to the aspiring technical writer. At present, however, the available courses do not comprise an adequate curriculum for the education of a technical writer or editor.

In the Metropolitan Detroit area, four major universities offer noncredit courses in technical writing through their adult-education programs. The University of Detroit offers a course in technical report writing as does the University of Michigan Extension Service. Wayne State University (WSU) and Michigan State University Oakland (MSUO) both offer rather complete programs encompassing courses in technical writing, report writing, business writing, and speech. The courses offered by WSU are shown in Table I; those offered by MSUO are listed in Table II.

TABLE I - COMMUNICATIONS COURSES OFFERED BY WAYNE STATE UNIVERSITY, APPLIED MANAGEMENT AND TECHNOLOGY CENTER

Business English
Management and Technical Reports
Business Letters
Business and Public Speaking
Planning, Preparing, and Leading Business Conferences
Technical Writing for Engineers
Advanced Technical Writing for Engineers

TABLE II - COMMUNICATIONS COURSES OFFERED BY MICHIGAN STATE UNIVERSITY OAKLAND, DEPARTMENT OF CONTINUING EDUCATION

Business English
Report Writing
Communication in Selling
Technical Writing I
Technical Writing II
Business and Professional Speech
Effective Speaking and Leadership
Effective Speech
Psychology of Thinking and Communication

For the most part, the instructors for these courses are drawn from industry. Thus, the courses are taught by experienced, practicing writers and editors. Both universities have worked closely with industry in developing these programs. MSUO's Department of Continuing Education is now setting up an advisory committee, made up of representatives from industry and the university, to study the program now offered and to suggest additional courses and modifications. Hopefully this action will lead to an expanded program covering all of the communication skills needed by business and industry.

Detroit industry is supporting this work to the extent that several companies reimburse their employees for the cost of tuition and books upon satisfactory completion of a course. Some companies permit their employees to leave work early on the day of a class.

Company-Sponsored Courses

Here, the picture is not so promising. Few of the major companies in the Detroit area offer on a continuing basis courses in technical writing for their engineers. In the past, some companies have offered courses in report writing, with varying degrees of success. Others have brought in outside consultants, again with varying degrees of success.

Recently one Detroit company sponsored a course in technical report writing for its engineers, in conjunction with MSUO. This course, tailored to the specific needs of the company, was held evenings at the university and was limited to employees of the company. On the whole, the course was well received; many of the participants commented, however, that the course was too specific.

In my own company, we are currently presenting a basic technical writing course. It is too soon to tell how successful it will be. However, the program has been well received by our staff thus far. Enrollment in the classes is entirely voluntary, and the response from our engineers has been gratifying. Our major problem is finding the time to schedule the classes so that they will disrupt our work as little as possible.

To summarize the status of company-sponsored courses in the Detroit area, the consensus is that industry in general prefers to rely upon the courses offered by our local universities, perhaps supplementing these programs with occasional courses oriented to the specific needs of the organization. Others rely completely upon the technical writers and editors on their staffs to translate the output of their technical personnel into an understandable form.

Teaching Technical Writing to Engineers

In developing the technical writing courses offered at WSU and MSUO, we were fortunate in being able to draw upon the experience and knowledge of many professional technical writers and editors in the Detroit area and upon information published by the Division of Chemical Literature of the American Chemical Society, PGEWS, the Society of Technical Writers and Publishers, and the publications of other similar organizations. We were especially fortunate in being able to benefit from the valuable experience gained by the Publications Branch and the Training Department of Chrysler Corporation Missile Division in a highly successful on-the-job training program for technical manuals writers. This program was the subject of a symposium held during the April 1960 national meeting of STWP. For those interested in the details of Chrysler's program, the papers presented in the symposium can be found in the proceedings of that meeting.

Establishing a Philosophy

As we started to develop the technical writing courses for engineers we asked ourselves these questions:

1. What is the engineer's purpose or objective when he writes--what is he trying to achieve?

2. To whom does the engineer write? Who are his readers?

3. What does the engineer-writer expect of his readers?

4. What does the engineer need to know to achieve his objective?

From the answer to these questions, we developed a basic philosophy upon which we built our courses. This is our philosophy.

1. The engineer's chief objective in writing is to inform his readers of certain facts or circumstances as clearly and effectively as possible. This is true whether he is writing a memorandum, a progress report, a training manual, or a proposal.

2. He is writing to adult readers who fall, generally, into three groups: engineers in his own field; engineers in other fields; informed, intelligent laymen such as nontechnically trained management personnel. Occasionally he may write to a fourth group, the lay public.

3. He expects his readers to understand and act upon the information he has communcated.

4. To achieve his objective he needs to know these things:

a. The fundamentals of English Composition, including grammar; sentence structure; punctuation; the use of hyphens, abbreviations, signs, and symbols.

b. The techniques of description, instruction, exposition, narration, and, sometimes, persuasion.

c. Outlining and organization--the techniques of effective presentation.

d. Something of the psychology of the communication process--how people learn. He needs to know for instance, when text should be replaced or supplemented by an illustration, what kind of an illustration he can use, when he must avoid higher mathematics.

e. The mechanics of setting up tables of data.

f. The processes of producing a finished document so that he can plan and schedule his work intelligently. For example, the engineer would know how long it should take a graphic arts group to produce finished artwork so that he does not ask for the impossible.

In short, our underlying philosophy is that the engineer needs and wants a practical course designed to help him learn to present technical information as effectively as possible in carrying out his duties as an engineer.

Determining Course Content

From this philosophy evolved the basic two-semester course shown in Tables III and IV. Each session lasts 2 hours. At MSUO, each semester is 10 weeks long. At WSU, the same material is covered in 12 weeks.

TABLE III - FIRST SEMESTER

SESSION	SUBJECT
1	Objectives and Responsibilities of the Engineer-Writer; Reader's Viewpoint
2	Grammar and Sentence Structure; Outlining and Organization of Material
3	Punctuation; Abbreviations, Hyphens and Other Mechanics of Writing; Techniques of Description
4	Paragraph Development; Techniques of Instruction
5	Style and Correct Usage; Techniques of Exposition
6	Memorandums; Techniques of Narration and Persuasion
7	Informal Reports; Illustrations and Tables
8	Semester Project
9	Critique
10	Critique and Course Summary

TABLE IV - SECOND SEMESTER

SESSION	SUBJECT
1	The Communication Process; Psychology of Writing to Various Technical Levels
2	Analysis of Sample of Technical Writing Directed to Various Technical Levels
3	Effective Use of Illustrations with Respect to Technical Level of Reader
4	Formal Reports; Techniques of Persuasion
5	Proposals
6	Sales Literature and Technical Advertising
7	Format and Layout
8	Semester Project
9	Critique
10	Critique and Course Summary

Having determined what the engineer-writer needs to know, we then had to decide how to teach him.

Teaching Techniques Used

We then drew up a series of check lists covering the most common problems encountered in the mechanics of composition: grammar, sentence structure, punctuation, hyphens, abbreviations, etc. To supplement the check lists, we developed a series of exercises incorporating these problems. The students discuss and correct the examples in class while using the check lists as guides. The samples consist of sentences and paragraphs taken from technical documents from many engineering and scientific disciplines. We consider it of utmost importance to deal with technical terminology throughout the course.

This editorial approach is carried on throughout our work on descriptions, instructions, and all other techniques and subjects.

Because we believe the best way to learn to write is to write, we further supplement class discussions with writing assignments to be done as homework. Our students are required to write physical descriptions, functional descriptions, operating instructions, explanations of processes and theories. We give pop quizzes from time to time. The instructor discusses each assignment with each student individually. The students analyze and rewrite many sample paragraphs, each designed to point out a specific problem in presentation. Finally the student is assigned a semester project which he writes partially in class and partially away from class. Here he tries to apply in greater detail one or more of the techniques covered during the semester. At the end of the semester each student receives a grade. If he completes the course satisfactorily, he receives a certificate of completion from the University.

During the first semester, we emphasize writing to a low technical level, that is, the intelligent, well-informed adult. We have taken this approach because we believe that if one can communicate technical information to nontechnically trained persons, he will have little difficulty in communicating with technically trained persons.

In the second semester, we spend much more time on the psychology of technical writing and in trying to determine what information the reader really needs as well as what he thinks he needs.

We try to be flexible in our course content so as to give each student instruction in the areas where he is weakest. Further we permit the student to substitute for some of the assignments writing that is closely related to his own work. At the end of the first semester we urge the student to write about something directly related to his work. In the second semester we try to have the student broaden his viewpoint. Here we ask him to choose a subject related to his daily work but to write a different type of document than he ordinarily does in his job.

We try to offer the most practical help to the engineer that we can. Because we cover many subjects in an extremely short time, we cannot cover them as well as we would like. We try not to let a weak student hold the class back. If a student is weak in the fundamentals of English composition we suggest ways of strengthening himself by doing extra assignments and studying other textbooks. In some cases we recommend that a student take a basic course such as Business English before continuing with the second semester of technical writing.

By the end of the second semester we consider that our students are reasonably competent writers. We urge them, however, not to stop here but rather to continue to improve their communication skills by taking courses in report writing, letter writing, etc.; by taking company-sponsored courses if they are available; by carrying out self-tutoring programs; and by participating in groups such as PGEWS.

We feel we have brought them to the point of being competent communicators of technical information. We challenge them to change competence to excellence, to be professionals in the fullest sense of the word.

PLACEMENT OF TECHNICAL PAPERS FOR MAXIMUM EFFECTIVENESS

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SUMMARY

This paper supplies answers to the many questions engineer-authors have raised with regard to selecting a suitable publication for their technical papers. It includes a description of the three major categories of technical magazines related to the electronics field: (1) the professional society publications; (2) company publications of a professional caliber, and (3) commercial technical magazines. Differences among the publications in these three categories are discussed. Subjects covered include the editorial review and technical evaluation procedures, submission requirements as to illustrations and number of copies, handling of publications, payment policies, availability of reprints, and the like.

The engineer who spends many hours writing a technical paper wants to and deserves to reach a large group of readers. The readers, however, must be a "knowledgeable" group so that the information will not only be of benefit to them but will also bring credit to the author and his sponsoring company.

With the hundreds of technical publications and dozens of professional society meetings each year, the engineer-author often has a problem in selecting the right publication or platform for his material. This paper describes some of the technical publications and their methods of operation so that the choice will be an easier and more profitable one.

Types of Publications

On a broad basis, the technical publications that electronics engineers read and write for can be divided into three categories: professional, company, and commercial. Professional publications are those issued by the professional societies and include the PROCEEDINGS OF THE IRE, the CONVENTION RECORDS, the AIEE ELECTRICAL ENGINEERING, the IRE Professional Group TRANSACTIONS, and the like. The second group includes publications of a professional nature issued by industrial companies. Examples of publications in this group are the RCA REVIEW, BELL SYSTEM TECHNICAL JOURNAL, and IBM JOURNAL. The third group, publications issued by commercial publishing organizations, is the largest and includes publications like ELECTRONICS, ELECTRONIC DESIGN, ELECTRONIC EQUIPMENT ENGINEERING, ELECTRONICS WORLD, AUDIO, and many others.

There are several major differences among these groups of magazines. They differ in readership, emphasis, editorial review procedure, submission requirements, and payment practices. In addition, there are substantial differences among the magazines within the groups. With a knowledge of these differences, the engineer-author will be better able to select the right publication for his writing efforts.

Professional Society Publications

Among the aristocrats of the technical publications field are the major publications of the professional societies, such as the IRE PROCEEDINGS or AIEE ELECTRICAL ENGINEERING. These publications are considered by many to be essentially publications of record. Papers are accepted and published with the expectation that they will be of permanent value as reference material. Papers submitted to a publication in this group are usually reviewed by volunteers from the society membership who are experts in the particular field of the paper under consideration. The review cycle may be fairly long (several months and occasionally much longer), and may include several reviewers. If changes or additions are suggested, the author is asked to provide them. To facilitate the review procedure, the author is asked to submit three to six copies of his paper. Upon its acceptance, he is also asked to submit reproducible copies (including inked master drawings) of his illustrations. The professional societies do not remunerate the author; in fact some of them, such as the Physics societies, make a publication charge of up to forty dollars a page. The publication of a manuscript by a professional society journal provides the author and his sponsoring organization, company, or university with prestige, an intelligent readership, and, of course, a substantial amount of professional satisfaction.

A number of other professional societies besides the IRE and the AIEE publish papers related to the electronics field. Publications of some of these societies are shown in Chart I. This chart shows the publication, sponsoring society, frequency of issue, and approximate circulation figures. The circulation figures are based on average circulation in the first half of 1961 as obtained from STANDARD RATE AND DATA.

Apart from the PROCEEDINGS, the IRE is a very prolific publisher of a wide variety of technical material. It sponsors the TRANSACTIONS of 28 different professional groups, the RECORDS of its major international meetings, and the publications resulting from a host of regional or specialized meetings. In addition, it is responsible for the Professional Group newsletters, the STUDENT QUARTERLY, and the section publications ranging from newsletters to glossy magazines.

NAME	SOCIETY	ISSUED	CIRCULATION*
PROCEEDINGS OF IRE	IRE	Monthly	76,000
PG TRANSACTIONS	IRE	Varies	Varies
ELECTRICAL ENGINEERING	AIEE	Monthly	53,000
TRANSACTIONS	AIEE	Varies	Varies
PHYSICS TODAY	AIP	Monthly	32,000
JOURNAL OF APPLIED PHYSICS	AIP	Monthly	9,000
REVIEW OF SCIENTIFIC INSTRUMENTS	AIP	Monthly	9,000
ISA JOURNAL	ISA	Monthly	21,000
SCIENCE	AAAS	Weekly	68,000
ASTRONAUTICS	ARS	Monthly	22,000
JOURNAL OF SMPTE	SMPTE	Monthly	
JOURNAL OF AES	AES	Quarterly	3,000
AEROSPACE ENGINEERING	IAS	Monthly	20,000

* Circulation figures are based on average circulation in first half of 1961 as obtained from STANDARD RATE & DATA.

Chart I - Some Professional Society Publications Covering the Electronics Field.

The TRANSACTIONS of the Professional Groups do not necessarily have the same standards and/or practices as the PROCEEDINGS. The papers accepted may be highly specialized and, perhaps, even less comprehensible to the nonspecialists than some of the PROCEEDINGS papers. The individual PG TRANSACTIONS vary in their acceptance and review practices, although some operate on a formal basis very much like that of the PROCEEDINGS. The circulation of most of the Professional Group TRANSACTIONS is under 10,000 copies. The TRANSACTIONS of the Professional Group on Electronic Computers (PGEC) has a circulation of 11,500 at this writing, which is the largest figure for all the Group publications. Most Professional Groups publish their TRANSACTIONS 4 to 6 times a year.

The IRE Section publications usually seek semi-technical or non-technical material. Because of the scarcity of this type of material and a plethora of advertisements, these publications are often obliged to reprint a considerable amount of material from other publications.

Company Publications

A second group of publications of interest more as a reference source than as a publication medium to most engineer-authors is the company or house-organ type publications. Authors who work for companies or organizations having such publications should study them carefully, for they offer a distinct opportunity. Most of these publications are issued to serve a number of important purposes. One, of course, is to present a worthy company image. Another is to provide an outlet for material, that cannot readily obtain publication elsewhere because it is either highly specialized or extremely long. The BELL SYSTEM TECHNICAL JOURNAL, for example, has published many papers on telephone-communications subjects that no other periodical could afford to consider. On the other hand, it has also published pioneering articles in fields that other publications were not ready for at the time.

Further attractions of a house organ are that it can publish promptly, is flexible as to number of pages, and, if necessary, can hold up an issue for an important article. Review and payment practices of these publications vary. The RCA REVIEW uses RCA scientists as reviewers and makes a small token payment to each author on publication. The IBM JOURNAL, on the other hand, pays its reviewers, who are recruited from outside the company, but does not pay its contributing authors. The BELL SYSTEM TECHNICAL JOURNAL and the SPERRY ENGINEERING REVIEW do not pay either the authors or the reviewers a special remuneration.

Commercial Publications

The most varied and the largest group of publications is the commercial group, the magazines issued by commercial publishing organizations. This group is often the most attractive to the engineer-author. The editors vigorously solicit articles. When published the articles are often glamorized by eye-attracting editorial or pictorial treatment, and there is some financial remuneration for the author. Quality standards for this group of publications differ from those of professional society publications, but are not necessarily lower.

The commercial publications have members of their staff review submissions. Although these editors have varying degrees of expertness in technical areas, they usually have a good idea of what their readers want. When submitted articles are not up to the quality standards of the publication or do not fit the space requirements, the editors will, if the subject matter warrants, work with the authors (or in some cases without them) to upgrade the material. In some cases the magazine staff will rewrite the article submitted to a considerable extent. The author may be consulted on the changes, but he is often offered a "fait accompli" in the form of galley or even page proofs and a very close deadline. Although this procedure may disturb the feelings of some authors, the resultant articles are usually a considerable improvement over what was submitted. Occasionally, however, some embarrassing technical errors result from cavalier editing; therefore, the author should review proofs very carefully.

The best and safest procedure is to submit the article or paper in good shape and with the right slant for the particular publication so that no editing will be required and acceptance will be practically on sight. The review cycle can be fairly short. Some of the commercial publications accept or reject articles in less than two weeks. Others take even longer than the professional societies.

A further mark of distinction for the commercial technical publications is that almost all of them pay the author for his material. Payment averages about $25 a printed page, including illustrations. Payment alone is usually not a sufficient incentive for the busy engineer to write an article. Satisfaction, prestige, and commercial position are more significant rewards.

New technical fields have spurred new magazines at a rapid rate even surpassing the growth of the IRE Professional Groups. Chart II lists a number of commercial magazines grouped according to major field. Circulation figures are based on the same source as Chart I. Some of these magazines have specialized in narrow technical areas which have considerable growth potential. In the microwave field, for example, there are the MICROWAVE JOURNAL and the new one MICROWAVES. In the semiconductor field, there are SEMICONDUCTOR PRODUCTS and SOLID STATE DESIGN. In the space-electronics field, there are MILITARY SYSTEMS DESIGN, SPACE AERONAUTICS, and MISSILES AND SPACE. In the data-processing or control field, there are AUTOMATIC CONTROL, AUTOMATION, CONTROL ENGINEERING, and several others.

There is another group of commercial technical publications, not listed in Chart II because they are of practically no interest for technical articles, which are a good source of information on new products and technical literature issued by manufacturers. These publications include INDUSTRIAL EQUIPMENT NEWS, ELECTRICAL DESIGN NEWS, and INSTRUMENT AND APPARATUS NEWS. ELECTRONIC PRODUCTS started out in this category, but has enlarged its scope and is now publishing several technical articles in each issue.

The commercial publications which do not specialize in a limited technical area include ELECTRONIC DESIGN, ELECTRONIC EQUIPMENT ENGINEERING, ELECTRONIC INDUSTRIES (temporarily called TELE-TECH), ELECTRONIC PRODUCTS, ELECTRONICS, and WESTERN ELECTRONIC NEWS. These publications operate in a business-like manner; they usually acknowledge receipt of manuscripts, review them promptly, and publish them promptly. They are not all equally efficient, and even the best have occasional lapses, but on the whole authors find them cooperative and competent.

Another part of the technical publications spectrum includes the journals that are read by service technicians, experimenters, radio amateurs, audiophiles, as well as by many engineers who may double in the above categories. Publications in these groups include ELECTRONIC TECHNICIAN, ELECTRONICS ILLUSTRATED, ELECTRONICS WORLD (one-time RADIO AND TV NEWS), POPULAR ELECTRONICS, RADIO ELECTRONICS, PF REPORTER, AUDIO, and the radio amateur publications QST, CQ, and "73". (It could be argued that QST belongs in the category of professional society publications because it is the organ of the American Radio Relay League, a membership group. It has high standards of technical quality, good editing, and many distinguished contributors, and, like the publications of the Professional Societies, it does not pay its contributors.)

Each of the magazines mentioned above has a distinct personality. Some of them, like ELECTRONICS WORLD and RADIO-ELECTRONICS, have circulations running into the hundreds of thousands. Most pay

NAME	ISSUED	CIRCULATION*
GENERAL		
ELECTRONIC DESIGN	Biweekly	38,000[c]
ELECTRONIC EQUIPMENT ENGINEERING	Monthly	41,000[c]
ELECTRONIC INDUSTRIES	Monthly	58,000[c]
ELECTRONIC PRODUCTS	Monthly	57,000[c]
ELECTRONICS	Weekly	54,000[a]
WESTERN ELECTRONIC NEWS	Monthly	19,000[c]
MILITARY-SPACE		
MILITARY SYSTEMS DESIGN	Bimonthly	38,000[c]
MISSILES & SPACE	Monthly	24,000[c]
SPACE AERONAUTICS	Monthly	58,000[c]
INDUSTRIAL		
ELECTRONIC PACKAGING & PRODUCTION	Bimonthly	15,000[c]
ELECTRO-TECHNOLOGY	Monthly	32,000[c]
INDUSTRIAL RESEARCH	Monthly	41,000[c]
PRODUCT ENGINEERING	Biweekly	51,000[a]
RESEARCH DEVELOPMENT	Monthly	34,000[c]
CONTROLS, AUTOMATION, DATA PROCESSING		
AUTOMATIC CONTROL	Monthly	37,000[c]
AUTOMATION	Monthly	33,000[c]
COMPUTERS & AUTOMATION	Monthly	4,000[c]
CONTROL ENGINEERING	Monthly	32,000[a]
DATAMATION	Monthly	31,000[c]
INSTRUMENTS & CONTROL SYSTEMS	Monthly	32,000[c]
SERVICE TECHNICIAN		
ELECTRONIC TECHNICIAN	Monthly	82,000[a]
ELECTRONICS WORLD	Monthly	240,000[a]
PF REPORTER	Monthly	74,000[a]
RADIO-ELECTRONICS	Monthly	156,000[a]
HOBBY, EXPERIMENTER, POPULAR		
CQ	Monthly	92,000[a]
ELECTRONICS ILLUSTRATED	Bimonthly	187,000[a]
ELECTRONICS WORLD	Monthly	240,000[a]
POPULAR ELECTRONICS	Monthly	388,000[a]
POPULAR SCIENCE	Monthly	1,260,000[a]
QST	Monthly	105,000[a]
RADIO-ELECTRONICS	Monthly	156,000[a]
SCIENTIFIC AMERICAN	Monthly	300,000[a]
73	Monthly	34,000[a]
OTHER		
AUDIO	Monthly	25,000[a]
BROADCAST ENGINEERING	Monthly	8,000[c]
MICROWAVE JOURNAL	Monthly	22,000[c]
NUCLEONICS	Monthly	20,000[a]
SEMICONDUCTOR PRODUCTS	Monthly	13,000[b]
SOLID STATE DESIGN	Monthly	20,000[c]

* Circulation figures are based on average circulation in first half of 1961 as obtained from STANDARD RATE & DATA.

[a] Paid circulation.

[b] Paid circulation about 75%.

[c] Controlled circulation.

Chart II - Commercial Technical Publications Listed by Major Field.

THE ENGINEERING REPORT, A RUSTY TOOL

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Summary-This paper considers the importance of adequate engineering reports, their practical use in industry and government, and general rules for simplifying the preparation of complete, concise reports. Although the ideas are not new, they are presented in a manner intended to shake the apathy of the typical engineer. The paper points out that most engineering personnel shy away from one of their most valuable tools because they look at it as a burden. However, since many important ideas and test results have been lost because of inadequate engineering records and reports, the engineer must recognize his responsibility in this area. The body of the paper is devoted to presenting general rules to simplify the preparation of engineering reports. It discusses items such as the recording of data and facts, the various report forms, the report outline, the reader to whom the report is directed, and the actual writing of the report. The paper is concluded by a check list to help the engineer verify that his report has fulfilled its objectives.

Introduction

No engineer would consider working without his slide rule and reference tables. A technician would be lost without his soldering iron and VOM meter. However, most engineering personnel indifferently overlook an equally valuable tool, the engineering report. Why? It is primarily because they don't realize the full importance of the engineering report. A secondary reason is that most engineering personnel feel that the preparation of reports is a burden and an unnecessary waste of their valuable time. The report writing period should be welcomed by an engineer as a creative pause during which he can review, analyze, and organize what he has done. The goal of this paper is to point out the importance of engineering reports and suggest a few rules to simplify the task of preparing reports.

Figure 1 - A Rusty Tool ?

Importance of Reports

The engineering report serves two purposes: first, it establishes a permanent record of the task accomplished and the events leading to the completion of the task; second, it serves to disseminate valuable engineering information and ideas. Searching for data in reports and published referenced texts is a recognized and widely used technique. To the research reader, these publications represent valuable information on work that has already been completed by the writer. A well-written report eliminates duplication of effort and saves valuable engineering time for application to basic study.

Many large industrial corporations and universities engaged in long range engineering programs may not produce anything for long periods but reports of their work. Future plans are often based on the content of these reports. In other cases, where pure research is concerned, the only products delivered to the customer are engineering reports. The quality and value of the task accomplished is judged by the content of the report. A well-prepared report acts as a silent salesman for the company. On the other hand, an inferior report is a significant detriment to a company's prestige.

The Government also places considerable emphasis on the preparation of reports. The operations of many governmental agencies depend on intricate reporting systems. The various military agencies are particularly aware of the importance of engineering reports. Several million dollars of the defense budget are annually devoted to the preparation of reports. In fact, a special agency, ASTIA (Armed Services Technical Information Agency), has been established solely for the purpose of handling engineering reports and other associated information. These reports are used as a means of disseminating valuable technical information among the various military services.

Professional societies have long recognized the importance of the communication of ideas by means of technical papers and reports. The heart of most engineering conventions and symposiums is the presentation of technical papers. Without this media, many valuable ideas and techniques would have been doomed to obscurity and lost to the engineering profession as a whole. These papers have also been instrumental in the establishment of technical standards for terminology, symbology, units of measure, etc. Without this media, the engineering profession would be lost in a maze of technical jargon with its members unable to intelligently communicate either among themselves or with those outside their profession.

The engineering report is also important to the individual engineer. Almost every well-known scientist and engineer is recognized because he accurately recorded his work. Newton, daVinci, Galileo, and in more recent times, Hartley, Zener, Goddard, Marconi and many others are familiar names in the fields of science and engineering. A new concept, first presented as a paper before a technical symposium, endured because the writing of it provided a means of disseminating the idea throughout the engineering world. Today, Einstein's theory has forceful reality. However, without the written record, and the challenge it presented to scientific investigation, this theory might not have survived the 40 years from promulgation to practicality. It is a well-established fact that many valuable ideas or techniques have gone unnoticed until someone has taken the time to document them. As a result, the actual originator is not recognized simply because he did not adequately document his work. In reality, the job is only half done until it is clearly and completely recorded for others to use.

Where Does the Report Begin?

The engineering report begins when the project is started, not with the completion of the project. Careful organization of the required information is extremely important. During the course of a project, every significant event, all test data and observations, various pertinent memos, letters, receipts, etc., and any other associated information must be carefully accumulated. The best way to accomplish this is to extablish a logical filing system at the start of a project. The various phases and requirements of the task should

Figure 2 - Organize the Information

be analyzed to establish a logical system for the filing system. Once the filing system has been setup, it should be tested for a few weeks to see how well it works, after which any necessary adjustments may be incorporated. When a working system has been set up, it should be continuously maintained. Not only will a good filing system simplify the preparation of required engineering reports, it will also help the engineer perform his routine daily functions more efficiently and with a minimum of confusion. Most engineers would consider this an unnecessary waste of time, but in the long run, it would save him many hours of fruitless searching and duplication of effort.

In carrying out the various phases of the project, an engineer should look ahead to the preparation of the report. Special attention should be given to information and data that might be particularly useful in preparing the report. All pertinent papers should be retained no matter how irrelevant they seem at the time. Their value may increase with time. Accurate records should be maintained of the contacts made during the course of the project and of the various meetings attended with regard to the coordination of the project. Sketches of all test circuit diagrams and the equipment used should also be accurately recorded so that they can be duplicated if necessary. All data, including, false starts and any other seemingly erroneous information, should be kept and filed, taking special care to clearly identify the data and the manner in which it was obtained.

Photographs are particularly useful in the documentation of project results. Photographs of test setups, equipment construction and layout, assembly techniques, component failure or damaged parts, and other similar information help to clarify the written data. They can also simplify the routine operations of an engineer by literally bringing the project to his desk. With the availability of relatively inexpensive, high-quality Polaroid equipment, the task of taking pictures is greatly simplified. Polaroid recordings of oscillo-

Figure 3 - Photographs Simplify and Clarify

scope presentations of waveshapes, phase angles, and other signal characteristics are particularly useful to the engineer, provided care is exercised in obtaining and annotating the records. These photographs can later be useful in preparing the engineering report. They help to reduce the descriptive material necessary and might be of considerable assistance in emphasizing a particular point. However, records of any type are of little value unless they are clearly annotated as to what they are and how they were obtained.

Developing a Plan

After a project has been in existence for awhile, a logical outline can usually be developed. Most all engineering reports have a basic outline similar to the following:

Figure 4 - Develop a Plan

I Introduction
II History of Project
III Description of Results
IV Conclusions and Recommendations
V Summary

In addition, an abstract should be included in the beginning of most engineering reports to present a reader with a concise picture of the contents of the report. This is particularly valuable in the present accelerated business environment, and in reports intended for a non-specialist audience. Suspense is important in detective stories but has no place in an engineering report.

In order to prepare a logical outline, it is important for an engineer to know his subject completely. The various requirements of the project should be thoroughly reviewed. In many cases, the detailed outline

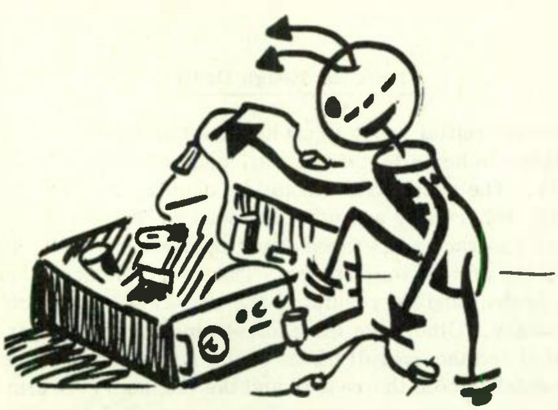

Figure 5 - Know Your Subject

can be based on the specification or work statement for the project. In other cases, the detailed outline can be based on the various phases in which the project is completed. In still other cases, the outline is dictated by the project results or the use to which the end item will be placed. A report concerned primarily with documenting the results of a test or a series of tests would differ considerably from a report covering the development of an item of equipment. The engineering progress report is still another type of report. Every report is different in detail, but their outlines are like theatrical plots, only a few truly unique outlines exist.

One of the most important factors in preparing an outline is assuring its completeness. All phases of the project must be considered. If certain phases were cancelled or were relatively insignificant, this should be clearly noted. If this information is omitted, it leaves a question in the mind of the reader. The familiarity an engineer has with a project can often be a detriment. He is often forced to spend so much time on relatively unimportant details that the important ideas begin to lose their proper perspective. This may result in important ideas being buried in a mass of details. Careful consideration of the purpose and scope of the project will help the engineer to keep his ideas in proper focus and will ultimately result in a clearer presentation of the required information to the readers.

Preparing the Rough Draft

After a logical outline has been completed, a rough draft of the report can be started. The engineer should check his files and review all available data to refresh his memory. He should then try to write the

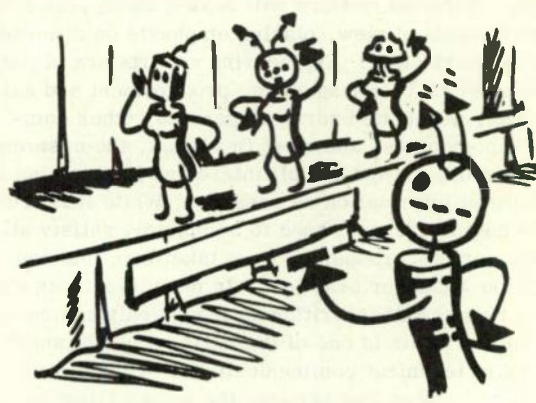

Figure 6 - Review the Available Data

first draft in one great effort. In the first draft, the engineer should put down all facts that may be significant. He should write in a full, free style, without concern for possible repetition or wordiness. Attempting to write too cautiously at the start usually results in a stilted and incomplete story.

The first rough draft will probably be very rough indeed, but the details of sentence structure and grammar can be easily repaired during subsequent efforts. Special attention should be given to organization and coherence; however, if the outline is followed religiously, the finalization of a report is greatly simplified.

In preparing the rough draft, the ultimate readers should be considered. One of the basic problems in the communication of technical information is the writer's failure to consider the reader. Too often the engineer thinks only of what he wants to say, rather than considering what the reader wants to know. He is so intent on giving expression to his ideas that he gives little attention to the impression he should be leaving with the reader.

Figure 7 - Consider the Reader

Different types of readers have different educational backgrounds, which may or may not be technical. In addition, different readers will review the report from different points of view, placing emphasis on different types of information. Engineering reports are of particular interest to management, procurement and sales personnel, associated service agencies, other commercial companies, and most important, the customer. These various groups are all interested in obtaining as much useful information as possible. While it is true that an engineer cannot hope to completely satisfy all of these various groups, he must take them into consideration whenever practical. In many instances an engineering report is written as though only engineers will read it. This is one of the most prevalent shortcomings of technical communications. The point of the report is often lost because the writer failed to consider the knowledge of his typical reader. The engineer must ascertain the knowledge level at which he is to write and then be consistent in maintaining that level. All too often, important information is taken for granted, leaving the reader stranded and confused.

This not only hurts the value of the report, but it can also hurt the interests of the engineer by failing to put across an important point. However, the engineer should realize that there is a distinction between "knowledge" and "intelligence". The engineer should be careful never to insult the intelligence of his readers. In addition, the engineer must keep in mind that his readers are interested in information, not entertainment.

In preparing the rough draft, considerable thought should be given to the illustrations to be used. These may take the form of photographs, block diagrams, sketches, schematic drawings, etc. Tables and graphs

Figure 8 - Illustrations are important

also are extremely important in supplementing test material. While the use of illustrations greatly enhances the value and clarity of an engineering report, they should not be used indiscriminately. Every illustration should serve a purpose. In addition, all illustrations should be as simple as practical and clearly annotated to show their relation to the text. The prudent use of illustrations can save the engineer many words and can usually convey an idea more reliably than can words alone. At first glance, the use of illustrations may appear to increase the cost of an engineering report but, in the long run, they more than pay for themselves in the writing time saved and the resulting reader effects.

Check the Rough Draft

After the initial rough draft has been completed, the writer can begin to check, edit, and correct the results. The rough draft should be checked for clarity, unity, coherence, and completeness as well as technical accuracy and grammatical correctness. Clarity is of the utmost importance. The report must describe the project and its results to the reader with perfect accuracy. Otherwise the contents might be misinterpreted and the overall effect of the report would be detrimental to both the reader and the engineer. A simple, direct presentation can best accomplish the desired results. Pompous, flowery, or individualistic expressions and unusual technical jargon that divert a

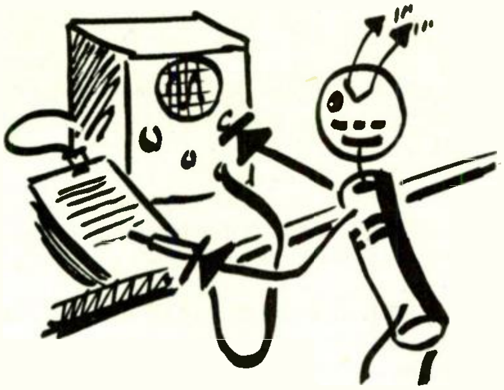

Figure 9 - Check the Rough Draft

reader's attention away from the important ideas have no place in an engineering report. The use of consistent terminology and the definition of unique or unusual terms are particularly essential to assuring the clarity of the report.

A report has unity when it includes all information related to the subject and eliminates all unnecessary material. Wandering from the subject, which usually results from carelessness or from a deliberate effort to pad the text, confuses the reader and wastes his time.

Figure 10 - Eliminate Unnecessary Material

By scanning the rough draft, the writer can easily spot and eliminate any portion of the test that is irrelevant. The omission of essential thoughts is usually more difficult to detect, but can be avoided by strict adherence to the established outline.

Coherence is achieved in a report when the thoughts contained therein unfold naturally and have the proper relationship with one another. Connective phrases and expressions may help to link parts of the text together but the use of such expressions should not be abused. In some cases, transitional paragraphs may be required solely to link other paragraphs effectively. A logical arrangement of the text, together with the prudent use of transitional expressions, will assure the desired coherence.

The rough draft should be checked against the outline to be sure that all the subject material has been adequately covered. At this point, it would be a good thing to have someone else read the draft to ascertain points of confusion. Their criticism should be carefully considered since small but important points can inadvertently go unnoticed because an engineer is too close to his work. This is also a good time to check the illustration references. Although illustration references may be utilized as often as necessary, every illustration used in a report should be referenced at least once in the text. This adds much to the coherence of the report.

After the writer is relatively satisfied with the content of the draft, he should recheck it once more for grammar, spelling, and consistency. Although conformance to the basic rules of grammar is absolutely essential, the engineer should not concern himself with the more subtle grammatical considerations. Technical reports are not expected to be literary masterpieces. However, accurate spelling is absolutely essential. If in doubt, the writer should always check the dictionary. Incorrect spelling is the sign of a sloppy report. The final polishing operation consists of a check of the consistency of the terminology. Nomenclature, capitalization, and abbreviations, particularly those that are unique or unusual, must be consistent throughout the report. Some engineers have the mistaken idea that the names or titles of objects or persons should be varied to keep the report from being dull. To reiterate, the engineering report is not expected to be a literary masterpiece. Accuracy and clarity are the primary requirements. They should never be sacrificed to make a report more interesting. One rarely sees lace etchings on a slide rule so why should an equally valuable tool be hampered by unessential frills? All good tools are kept well-polished.

Conclusion

The report is now ready for final typing. The exact form of the final draft is usually dictated by the standard practices of the company. The engineer should become thoroughly familiar with these requirements.

If an engineer is thoroughly familiar with his project, and has planned ahead for the report, the actual writing of the report is relatively simple. The following list contains a few brief rules to help simplify the preparation of engineering reports:

1. Establish and maintain a logical file system.
2. Plan ahead for the report during the course of the project.
3. Accurately record all pertinent information, including photographs and/or sketches of nonpermanent items.

4. Before starting any writing, prepare a logical outline.
5. Write the initial draft in one great effort, following the outline as closely as practical.
6. Consider the reader.
7. Check the rough draft thoroughly for clarity, unity, coherence, and completeness.
8. Recheck the draft for grammar, spelling, and consistency.
9. Prepare final draft in accordance with company standards.

Writing an engineering report is not difficult if the proper preparations are made and the task is approached logically as a challenge, not a burden. The engineering report is a valuable tool; it should not be allowed to get rusty.

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THE CONSEQUENCE OF CHOICE

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An engineer early in his career makes important choices, often without any weighing of alternatives. His professional competence is profoundly affected in consequence.

Many a man self-indulgently chooses to bury himself in the complexities of his daily work, evading the larger responsibility he undertook when he became a professional engineer. The consequent moral debility is none the less damaging for being insidious. You must have seen the effects among your colleagues. They are the ones who are always going to write up their findings, as soon as the work-load lightens, but whose interim reports are never quite understandable.

Why?

This incapacity for full professional accomplishment is often masked under the banality that engineers cannot write. There is neither evidence nor justification for this stricture on an obviously intelligent, well educated, and deeply committed group of men. Some, of course, do receive less than optimum instruction and practice in the arts of writing and speaking, but this lack does not at all account for the widespread and justified complaint about the unwillingness and inability of engineers to communicate effectively. Colleagues, subordinates, supervisors, and clients, all join in deploring the communication of engineers, but the proffered reasons are unconvincing.

The causes lie elsewhere than in the instruments of writing and speaking. They are products of each individual's view of himself and of his work. One need not adduce the Pierces, the Finks, the Ryders, or the other men of stature in this profession as evidence for what can be done by engineers who are on top of their jobs. You see around you every day men who know what to say about their work and how to say it.

It is with the others that we must concern ourselves, for they are the expensive and embarrassing members of the profession, because they have made the wrong choices. You may have observed their aversion to making decisive statements. Reports, memorandums, even replies to direct queries always seem to obscure the point, to miss the essence, to confuse details with meaning. The writers are not deliberately evasive; they are simply unable, after avoiding responsibility so successfully, to view their work in perspective, to see it in relation to a larger problem or a broader field. It is easy to immerse oneself in the delights of solving technological problems and to rationalize that self-indulgence into an apparent dedication to a job. For these men to communicate effectively requires a change in their point of view, an acceptance of professional responsibility and a disciplined assessment of their own work against its objectives, but this is a choice for which they too often lack the moral strength.

Another, less serious cause for ineffective communications is an historical consequence. Many engineers are inhibited from writing and speaking for an atavistic fear of words. In the history of philosophy and of science so much sterile argument and so many fallacious descriptions of the universe have apparently derived from the misuse of words that many men have turned from them in an attempt somehow to win closer to reality and to develop a more precisely controlled tool for analysis and explanation than our natural languages have provided in the past. Once men are made aware of this fear and become sophisticated enough to realize that any adequate systematic symbolism is subject to the same errors, their superstitions about verbalizing dissipate in the light of knowledge, and verbal communication becomes respectable, although never easy. These misinformed engineers need to learn that no model of our universe or of any important segment of it, regardless of the symbolism employed, can be better than its use nor freer of error than are our perceptions and our assumptions. Then they can choose to present their views in a natural language, with a proper sense of the danger of misunderstanding but also with a recognition of the probability of effective communication.

A third cause of major consequence to effective communication of engineers derives from still another moral choice. Some men are constitutionally unable to draw conclusions; others require a safety factor of 5 in the evidence before they will agree that rain is precipitated from clouds. Perhaps the most difficult men to help are those who can arrive at decisions but are morally unable to stand before others with their conclusions nakedly exposed to judgement. Their self-distrust is hard to eradicate, but they will not mature professionally without developing a justified self-confidence, and they will never communicate effectively until they are willing to draw sound conclusions and present them so that others can see meaning in the work being done. This state of mind is a direct result of sound education.

Engineering contributes largely to shaping the very core of human existence today, but the profession suffers from the personal irresponsibility into which many of its members have unwittingly drifted. To consider oneself too busy with gathering data, too engrossed in calculations, too immersed in design or production to have time for striking a balance at frequent intervals is an all too common self-deception among engineers. For the profession, the effects of this delusion are unfortunate, but for the individuals who suffer it the consequences are spiritually corrosive. That engineer who does not discipline himself to cast a trial balance in his work and to communicate its meaning effectively fails in his profession. To communicate is to comprehend for oneself the meaning, the relations, and the value of one's work. What responsible man will be denied knowledge of his own identity? It is a consequence of choice.