Administration of Natural Resources Research

Some Lessons From Industrial Research

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AND
STATE OF COLORADO
DEPARTMENT OF GAME AND FISH

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I. INTRODUCTION

Research administration, as anyone engaged in research or the management of research effort knows, presents a number of peculiar problems not ordinarily encountered in personnel management. In large measure, this is due to the fact that the sole product of research is ideas. Industry has been able to define a separation between management (or production) and research because the end product of management is a thing or things which can be counted, weighed, and sold, presumably for profit. In dealing with soils, waters, forests, and wildlife, these differences are less obvious because the final products of resource management may be almost as nebulous as the products of research. While it is true, for example, that resource managers are responsible for determining the volume of timber and the number of wild animals harvested from millions of acres of public and private lands, they also deal in such qualities as stabilized watersheds and aesthetic appreciation. These may even be the most important products of good resource management, but they defy objective evaluation in terms of products and profits.

Possibly because of these differences, resource managers have not paid as much attention as they might to the progress in research administration being made by industrial organizations—organizations which must obtain the greatest possible efficiency in every phase of operation if they are to show a profit. In attempting to attain maximum efficiency, industry has been willing to test methods and philosophies which represent radical departures from accepted administrative theory. Industrial research has profited from this experience, and it seems certain that resource research could profit as well.

II. METHODS

The basic impetus for the investigation reported here was received from *The Organization of Industrial and Scientific Research* by Mees and Leermakers (1950). In the light of my own experiences in wildlife research, the material in this book proved to be so interesting that I expanded the literature search to all conveniently available material. At this point, I found that research administration is not a parochial problem. Administrators in other scientific fields have been seeking solutions for years. The annual Conference on the Administration of Research is now in its seventeenth year, and transactions have been published every year; *Research Management,* a journal devoted to research administration papers, is in its sixth year of publication; and a large volume of books and papers, mostly describing research management methods in chemical and physical sciences, is available. Finally, medical science has contributed a number of extremely interesting studies on the psychology of creativity, originality, and motivation. While it was manifestly impossible to review all the literature of research administration, the selections cited here are considered to represent a more than adequate sample of current thought in the field.

As a secondary facet of investigation, I conducted a survey of some research organizations outside the natural resources field. In all, letters of inquiry were mailed to research directors of 70 industrial, governmental, and private organizations engaged in some form of research activity. More than 50 replies were received, and several unsolicited contributions were obtained from people to whom the original requests had been forwarded. Almost without exception, these replies demonstrated a considerable interest and an immediate recognition that research administration has specialized problems. The emphasis large industrial organizations place on this subject is implied by the fact that many letters were answered personally by Vice Presidents for Research instead of by subordinate officers or public relations specialists. One director, in fact, considered the subject so important that he called long distance from White Plains, New York, to allow a personal interview.

Finally, for a few research organizations, I interviewed the people charged with responsibility for research results. Again, I found a real appreciation for the special problems of research management. A list of the research directors interviewed and of individuals whose letters had direct application to this problem is presented, following the bibliography. Citations which refer to this list are not dated, but most replies were received during July and August of 1961.

Since this is essentially a review of literature, it contains many quotations from experienced research administrators. Wherever possible, the position and affiliation of authors cited is indicated in the text. In order to prevent too many quotes from destroying continuity, I have also included a series of quotation appendices which will help to demonstrate the uniformity of thought and opinion encountered. This uniformity is important for two reasons. First, I hope it will substantiate the fact that every attempt has been made to give a fair presentation. There were not many areas of disagreement, but wherever controversy did appear, both sides are presented. Second, uniformity throughout many disciplines of industrial research should demonstrate that the basic principles outlined are applicable to any form of research effort.

III. RESEARCH ADMINISTRATION

The theory and practice of research administration covers a wide range of material, but four general subjects were mentioned throughout the literature and correspondence. These four, personnel, research atmosphere, organization, and the director of research, provide the basic outline for my presentation.

A. Personnel

The first requisite of any research effort, and one which may be more important than all others, is the selection and retention of competent personnel (Appendix I). Resources for the Future, Inc., a nonprofit corporation for research and education in the natural resources field, recently conducted a study of planning, policy-making, and research activities in the Department of Interior. They concluded (Denver Post, May 22, 1961) that

> The creativity of the department will be determined above all else by its ability to attract and utilize people who are capable of producing and implementing ideas.

Dr. Kenneth P. Davis, Chairman of the Department of Forestry, School of Natural Resources, University of Michigan, has written (1960): "Personnel is the basic and all-important resource in research"; and Durward Allen (1954) lists the ". . . selection of men with proper training and aptitudes . . ." as the first requisite for good research.

However, what are proper training and aptitudes? Is there a "research type" which can be defined and recognized? These questions have no absolute answer, but some factors do appear to be more important than others. James Hillier, Vice President, RCA Laboratories, has listed five factors he considers indicative of the creative individual (1958):

1. A high level of native intelligence.
2. A complete dedication to and absorption in his field.
3. An appropriate educational background and experience.
4. A temperament which keeps him dissatisfied with the *status quo*.
5. A sensitivity to slight departures from the established pattern of his specialty.

Another list is suggested by Professor J. T. Guilford of the University of Southern California (Whiting, 1958). Four factors he considers characteristic of the creative person are:

1. Problem sensitivity . . . the ability to recognize that a problem exists.
2. Idea fluency . . . the ability to produce ideas or alternative choices in great quantity.
3. Flexibility . . . adaptability in approach to a problem.
4. Originality . . . the ability to produce not only a greater number of ideas or alternative choices but also ones which are fresh and novel.

Since most of these qualities are not of a type which can be evaluated on short notice, some industries have adopted a probationary approach which allows evaluation of men doing research before permanent commitment. According to Albert Hull (1947), the General Electric Laboratories looks first at college marks and the recommendations of professors. In this respect, a recommendation as conscientious and hardworking, but unwilling to take statements at face value, may be more important than good grades. Second, recommendations of alumni are used as a measure of how well the individual would fit into the company. And, finally, General Electric tries, if possible, to hire men on a trial basis, before graduation, so that their working relationships and habits can be observed.

Dr. Davis (1960—University of Michigan) wrote: "Perhaps it can all be summed up by saying that a good man—with research interest—is needed." Certainly this is true. Yet, a number of writers have pointed out that the qualities which contribute to research ability are not necessarily those which make a good administrator—or soldier—or doctor. Research scientists may or may not be different from other people, but the best ones cannot be identified if their qualifications are evaluated on the same scale that is normally applied to management and administrative positions.

In this respect, the selection and retention of research personnel for resource work may be further complicated by the fact that most resource research is conducted by governmental agencies which function under some form of civil service. When I asked Dr. F. W. Brown, Director of the Boulder Laboratories, National Bureau of Standards, about this, he replied, "Let me put it this way—Civil Service is no help." The Bureau of Standards is, of course, competing at a different level than most resource agencies, because physical scientists are in much greater demand today than biological scientists. Nevertheless, the basic problems are similar.

Initially, the low pay scales associated with most civil service positions make it hard to attract top-quality scientific personnel. For example, Dr. Ira H. Abbott, Director of Advanced Research Programs for the National Aeronautics and Space Administration reports (1961) that

> The salary problem is most acute in government, which, for many years, has lagged badly behind the prevailing rate, especially in the lowest and highest salary ranges. This makes it exceedingly difficult to recruit newly graduated scientists, especially at the Ph.D. level, and to retain the best men with several years of experience who have established recognition of their individual accomplishments.

Job security sometimes balances salary deficiencies at beginning levels, but many research directors simply expect a high turnover as their scientists gain experience. The result, and this seems particularly true in resource research, is that the more successful administrators develop a philosophy described to me by James B. Hale, Chief of Game Research for the Wisconsin Conservation Department. Mr. Hale conducts ". . . the best possible program to recruit and advance good new biologists" and then plans for a 6–10 year turnover. He feels that good men will advance in any case and writes that

> . . . an administrator should take advantage of this situation by encouraging voluntary self-improvement programs . . . and then making maximum use of the biologists' abilities while they are available.

Beyond the beginning levels, Civil Service registers are rarely used in recruiting experienced people. When a civil service agency is able to successfully "raid" another organization for personnel, the scientist involved usually appears on the list only *after* indicating a willingness to accept new employment.

Finally, some provisions of Civil Service make it extremely hard for a research director to manage personnel as effectively as his counterpart in industry. Under Civil Service, for example, it is often impossible for the research manager to transfer an experienced technician with no creative abilities to quality control or some other section where his talents could be of benefit to the organization. This means, as Dr. Lee E. Yeager, Leader of the Colorado Cooperative Wildlife Research Unit, has observed, that Civil Service is often a means of ". . . perpetuating mediocrity." The unfortunate result, in the words of Dr. Frank Jewett, first President of the Bell Telephone Laboratories (1945), is that

> . . . the setting is one in which a large number of the best of our scientific and technical men are reluctant to operate. As a result, there is a large tendency toward the expenditure of huge sums of money for what is essentially second-rate work done by those less-than-best men who are content to spend their lives as poorly compensated civil servants.

B. Research Atmosphere

Selection of competent personnel is only the first part of the research administration problem. The problem still remains to obtain the greatest possible value from the efforts of the research staff. Apparently, the most important factor in this respect is a nebulous quality called "research atmosphere". Although nowhere well defined, this factor is mentioned in one way or another by many writers on research administration (Appendix 2). Dr. Ira H. Abbott (1961–National Aeronautics and Space Administration) began a paper before an Office of Naval Research Seminar on Research Planning and Management with the following statement.

> The quality of the research in any laboratory is directly affected by the environment in which the scientists live and work. If the environment is one which attracts and holds scientists with outstanding skills and abilities, the quality of the research will be better than if such scientists are difficult to recruit and have a tendency to move on to other organizations.

And Charles Orth, 3rd (1959), writing for *Harvard Business Review,* says

> . . . the degree of productivity evidenced by laboratory personnel will depend on the degree to which the optimum climate for professional research work has been developed and maintained by research management.

The influences of a good research atmosphere are so important that they may even overcome deficiencies in the abilities and qualifications of research personnel.

> C. E. Weinland (1952) has pointed out that while many have believed that real creativity in art or science is born, and cannot be

developed, recent work by psychologists seems to offer considerable hope that . . . in the proper environment, creative capacity for research can be developed. (Leonard, 1955)

But what are the factors that create research atmosphere? Partial analyses have been compiled by a number of writers. Those of Simon (1947), Hillier (1958), and Orth (1959) are particularly penetrating. In summary, nearly all of the factors in the research climate can be related to professionalism and the fact that research personnel are often highly specialized and well educated. The differences between educational levels of research and production personnel in industry are usually greater than the differences in resource management, particularly in the light of the increasing trend toward college graduation as a prerequisite for positions in resource work. It is nevertheless true that research personnel tend to take a professional viewpoint and to identify with the functions of the executive branch.

One large group of research-climate influences, for example, can be related to professional recognition, and a second large group to professional freedoms. The remaining factors of research climate are less directly related to professionalism but have a direct influence on research output through their effect on staff morale.

1. *Professional Recognition*

For the man with long years of specialized training in his field and a necessarily long association with the academic world, recognition of his status as a professional can be extremely important. Failure to provide such recognition, both within and outside the organization, may reduce, or even cancel, his effectiveness.

a. Recognition Within the Organization

Within the organization, such recognition takes three general forms. One is related to policy formulation and confidence in research, another to compensation procedures, and the third to promotional policies.

(1) *Policy Formulation and Confidence in Research*

James Hillier (1958—RCA Laboratories) has written, "The continued existence of understood objectives is beneficial to creative thinking." And Colonel Leslie Simon, U.S.A., Director of the Ordnance Department Ballistic Research Laboratories (1947), says "It is necessary to have a long-range stable policy so that working conditions can be guaranteed." Yet, a Booz, Allen, and Hamilton survey, reported in *Harvard Business Review* (Randle, 1959), showed that a lack of policy concerning research was a critical problem for many of the companies examined. In 100 companies recognized for their research effectiveness, between 66 and 80% of the finance and accounting, personnel, sales, and manufacturing divisions had an established policy; but only 60% of the research divisions had one. Worse, only 21% of the research organizations had their policy statement in writing. No similar surveys of resource organizations have been reported, but it seems doubtful that the results would be greatly different.

Part of the basis for the influence of a lack of policy is an implied lack of confidence in research. One of the ". . . basic elements of the climate for creative research" (Orth, 1959) is recognition of the importance of research and the complete confidence of administration in research. Dr. S. D. Stookey, Manager of Fundamental Chemical Research for the Corning Glass Works (1958), lists as the first factor in a favorable environment for research that

> . . . every member of the management from the Research Supervisor through the Research Director to the Chairman of the Board of Directors must be genuinely convinced of the value of long-range research and ready to support it actively.

It is unfortunately true that, in periods of prosperity, research seems to enjoy a higher level of confidence than in periods of trouble. Yet nothing is quite so effective in destroying research atmosphere as a lack of confidence openly displayed by higher echelons of management. To quote Norman Shepard, Chemical Director of the American Cyanamid Company (1945)

> Top-management attitude toward research has a marked effect on the individual's contentment and efficiency. If it is clear, strong, unswerving support, day-in day-out, and year-in year-out, regardless of economic conditions to the extent that the financial strength of the company will permit, the worker knows he can follow through and with perserverance bring his work to a fruitful solution or logical stopping point.

There are several ways, in addition to having a written statement of policy, that confidence in research can and should be demonstrated. G. Forrest Drake, Vice President, Engineering and Research, Woodward Governor Company, lists ". . . a director who reports to the top of the organization . . ." as one of ". . . the characteristics necessary for proper function" of a research department. In addition, most writers agree with Frank Jewett (1945—Bell Telephone Laboratories).

> Wise management will see to it that those who direct its research and development organization are an integral part of its policy-making group.

That such a recommendation is actually being followed in industry is indicated by the number of research representatives on corporate Boards of Directors. Boehm (1957) has reported an M.I.T. survey of 151 of the largest U. S. manufacturers, in which it was found that 91 had vice presidents in charge of research. Maurice Holland, an Industrial Research Adviser (1947), has called the Director of Research the "Vice President of the Future" because the research director should know, better than any other individual, what the future has to offer his industry. An organization which does not take advantage of this knowledge is quite possibly not attaining full potential.

It may be necessary to separate research from the rest of the company functions, both physically and administratively, to attain the objectives of this recommendation; and it is the general opinion in industry today that research should be separated and placed on the same level as manufacturing and sales (Beal, 1943; Boehm, 1957; Hobson, 1960; and others). There are several advantages to such an arrangement, but the major ones as listed by George Beal, Assistant Director of the Mellon Institute of Industrial Research, are that:

1. The investigator is allowed to think in peace and quiet outside the normal bustle of production and business activity.
2. The investigator is in a position to view the whole operation with objectivity because he is not a direct part of production function.
3. The technical men won't be assigned to routine management emergencies.

There are also disadvantages connected with separation of research. Drucker (1952) lists "isolation from the business" as one of the major friction points between management and professional people; and the Booz, Allen, and Hamilton survey (Randle, 1959) found that a lack of effective personnel relations between divisions was one of the critical problems of research management. In fact, Dr. Robert Huntoon, Associate Director of the National Bureau of Standards (1957), reported

> Every survey I have heard about indicates that communication from management downward as viewed by the staff is an important problem.

As Norman Shepard (1945—American Cyanamid) points out

> Research people resent learning from the newspapers about their company's progress, personnel changes, some new or company plant that has been acquired or built. They like to feel they are in the family to the extent that they will be given confidences prior to the general public.

Accordingly, if research is separated from the rest of the business, provision should be made for adequate communication between research and other divisions at all levels. Where such communication exists, research productivity is invariably enhanced, and the confidence of management is justified.

Another effective method of demonstrating confidence in research is in utilization of the findings of research. Dr. Stookey (1958—Corning Glass Works) says

> . . . the atmosphere throughout the laboratory should be such that . . . the research man is confident of recognition of his work, and constructive application of results is made.

This seems fairly obvious, and yet it is not uncommon that research findings lie buried in some unread report until the competitor across the street comes up with the same results and capitalizes on them. When management then asks, "Why in blazes didn't you boys get that idea?"

(Wilson, 1949—Standard Oil of Indiana), there is a certain satisfaction in producing the original report; but it is considerably less frustrating for the scientist if research results are recognized when they are produced and evaluated on the basis of immediate application.

In this respect, it should also be noted that negative reports should receive as much attention as positive discoveries. Wilson says

> My own philosophy of handling research has been to give a good research director a stack of chips and tell him to get into the game and do his best.

Any research effort, then, is a gamble, and, except in very basic research where knowledge *per se* is the product, "The best scientist in the world can't tell *exactly* how a research and development project will come out." (Hobson, 1960).

This, of course, means that it is possible for a project to fail. It is extremely important that the scientist on such a project knows

> . . . he will receive due credit for his efforts if they have been conscientiously carried out, and that his promotion and salary increases will not be unfavorably affected by the fact that the problem assigned to him did not bear fruit (Shepard, 1945—American Cyanamid).

Dr. L. W. Bass, Vice President of A. D. Little, Inc. (in Discussion following Quinn, 1957) has said

> . . . it is essential that their technical effort be appraised and that they be complimented or otherwise upon the results they have obtained technically and not blamed for the economic failure of a project that may turn out that way.

Where such a policy is not followed, there is a very strong tendency for staff members to suggest and undertake only the easiest projects and those upon which success is virtually certain.

(2) *Compensation Procedures*

Considering the pay scales in most branches of resource management, it is obvious that a desire for money is not the major driving force for research personnel. As Justin Leonard (1955) noted in his paper: "The Future of Conservation Research"

> Surely, few young men today will train for and enter this field without motivations strong enough to overcome their desire for material gain.

Yet, Thomas Midgley, Jr. (1945) analyzed the situation thoroughly when he wrote

> It is quite true that scientists, as a group, are more willing to work for the sheer joy of satisfying their inquiring minds than are most other people; but it is also true that scientists have wives who want new automobiles and fur coats, quite as physicians' and lawyers' and judges' wives do, and scientists have children, just as other folks do, and scientists like to feel that they can raise and educate these

> children, as other folks do, and to do it they are deserving of an opportunity to obtain a financial reward that is somewhat proportional to the services they render society.

There are two facets of the monetary reward pattern which have received attention by professional research administrators. The first, and possibly the hardest to resolve under Civil Service, is the comparison with positions outside research. C. L. Gabriel, Vice President of the Publicker Commercial Alcohol Company, observed (1943) that

> . . . remuneration of the personnel should be in line with the top brackets paid in the locality for men of equal training and experience.

Concurring statements have been made by many authorities (Hillier, 1960; Randle, 1959; Simon, 1947 and 1947a; Wilson, 1949; Shepard, 1945; and others, Appendix 3). Salary is not usually considered the main motivating force for creative people, but the creative individual *is* motivated by the needs of his family. In a survey of a group of chemists by Professor Stein of the University of Chicago (1958), the top reward preference was for a substantial increase in salary.

That salaries in resource research are not competitive can be demonstrated by examining some of the comments I received in the mail and comparing them to the actual facts. James B. Austin, Administrative Vice President, Research and Technology, United States Steel Corporation, wrote, "In our Fundamental laboratory at least half of the professional people have a Ph.D. degree." Dr. M. G. Van Campen, Jr., Vice President for Research, Cutter Laboratories, said

> . . . group leaders and project directors should be highly educated and experienced in the basic science of their departments. This usually means that they have Ph.D.'s . . .

and R. L. Terrill, Vice President and Director of Research, Spencer Kellog and Sons, Inc., suggested, "You will certainly want as many scientists at the Ph.D. level as possible on your staff."

Let me say at this point that I am not trying to overrate the importance of advanced academic training. Mr. Austin qualifies his statement as follows

> In this connection I may say that we have found in some cases that a man with considerable experience in research in a given field can, over the years, become more competent than someone who has a Doctor's degree. My own view is that you can expect more from a man with a Ph.D. early in his career but as years go on the difference between the man with this kind of graduate training and others tends to become less.

and Dr. Van Campen continues

> . . . although we have several examples in our own group of men who do not have the formal Ph.D. degree, but their experience and ability is entirely adequate.

The point I am trying to make is that the expectation of these research directors, by implication at least, is for a heavy representation of post-graduate training in any research organization (Appendix 4). The same expectation has been expressed, for one branch of resource research, by Dr. Fred H. Dale of the Branch of Wildlife Research, Bureau of Sport Fisheries and Wildlife (1961).

> Today's wildlife research, if it is to go beyond that of the nineteenth and early twentieth centuries, must be based on use of modern scientific disciplines and techniques. It is questionable that this goal can be attained by a research staff in which no member has the preparation at least equal to that represented by the doctoral degree.

In resource research, we are not obtaining men with this level of training because there is almost no incentive for people primarily interested in research to seek the academic preparation required. We have a fairly large number of researchers with Master's degrees, but the majority of work at the doctoral level is done with the expectation of taking a teaching position, and the exceptions are mostly engaged in administration, not research. Resource research is in direct competition with the universities for highly trained personnel, and there is no indication that it is obtaining a proportion commensurate with its needs.

The pat answer to this problem is that, "If their pay isn't high enough they can find another job." Unfortunately, that may be just what happens. In 1956, the White House Committee for Scientists and Engineers in Federal Programs initiated an attitude survey to determine what was happening in government service. It was found (Siepert, 1957) that

> . . . two-thirds of the government scientists and engineers are dissatisfied with their prospects for salary advancement.

In resource work, our competition from industry for qualified people is not great enough to result in direct losses through 'raiding'. In fact, competition is almost nonexistent. Nevertheless, our personnel losses are just as great. For, as Dr. Dale observed

> Graduate students in selecting a field for study undoubtedly are influenced to a large extent by opportunities, both financial and cultural, for advancement. If salaries in . . . resource research continue to be far below those in such fields as chemistry, physics, medicine, and engineering, we must be content to take many men who for some reason have not been successful in meeting the requirements of the more lucrative competing fields.

(3) *Promotional Policies*

A corollary facet of the compensation pattern has to do with the standards for promotion and advancement. The average Civil Service rating, and, for that matter, the average rating in most business situations, places supervisory capacity at a premium. Yet Dr. Davis, Chairman of the Department of Forestry, University of Michigan, made the point that, "Research is an individual thing . . .", and Dr. C. E. K. Mees, Vice President in Charge of Research for the Eastman Kodak Company, has said (in Discussion after Midgley, 1945)

> . . . a research laboratory of any kind is made up of little cells, consisting of a scientist and a group of helpers, and as soon as the helpers get to be more than that particular man can direct—quite a small number—then a scientist from that group heads another group and forms another cell.

Thus, demonstration of supervisory capacity is no measure of scientific ability, and where supervision is used as a criterion it evaluates the collection of data in quantity, no matter how inferior, as superior to quality. Failure of management to recognize this relationship was considered one of the critical problems of research management in the Booz, Allen, and Hamilton survey (Randle, 1959).

One result of this premium on supervisory capacity is that advancement to more rewarding positions usually means promotion to administration. And this may actually be detrimental to a research organization. Dr. Herbert A. Shepard, Research Associate, Esso Standard Oil Company, (1958), notes that

> When a good scientist is made a manager, a good scientist is lost. Yet, promotion to management is the reward for competence in scientific work. Hence, the laboratory becomes a school for making non-scientists of its scientists.

This point is worth emphasizing, because the acceptance of the research division as a training ground for new employees is practically an occupational disease in many branches of resource work. Examination of nearly any resource management agency will show that the majority of college-trained administrative employees have served an apprenticeship in research. The resulting turnover leaves only three types of personnel to do research: 1) the new employee with his technical background as the only qualification for research, 2) the experienced technician who was not transferred to management because he was obviously incompetent in dealing with the public (and may be incompetent in research as well), and 3) the truly dedicated scientist who has refused transfer because he really understands and enjoys research. Since the odds are 2:1 against research in this classification, no further comment seems necessary.

Promotional policies may become even more complicated in those cases where individuals have demonstrated high-level scientific ability and almost no administrative talent. It is not uncommon to find a good researcher who, while highly productive and respected as a scientist, does his best work as a "lone wolf", cannot provide inspirational leadership, and may, as Drucker (1952) writes in *Harvard Business Review,* be

> . . . actually incapable of working with other people. To promote such a man to a position of command means destroying both him and the job.

Yet, as Robert Wilson (1949—Standard Oil of Indiana) notes

It is important to have an organizational pattern and salary scale that are flexible enough to provide such a man with an adequate reward in salary, even if he feels he works best by himself . . .

No absolute solution to these problems is available, but industrial research has demonstrated some significant trends in the attempt to provide an organizational structure in which

. . . the researcher can receive recognition and compensation equivalent to that which he might receive in administration. (Randle, 1959)

The major concept of industrial-research trends has been described by Boehm (1957).

Some companies give their nonadministrative scientists special titles —e.g., research associate, senior scientist, staff consultant—and many pay them as well as the administrators who are their nominal bosses.

Such a system can be implemented either through the use of nontechnical "administrative assistants" or by selecting scientific personnel with management abilities and, in effect, sacrificing their research potential in order to increase the potential of the remaining members of the staff through inspirational leadership and research-conscious administration. Both variations are based on the existence of parallel promotional ladders —one rewarding administrative ability and the other rewarding scientific accomplishment.

b. Recognition Outside the Organization

Scientific workers tend to develop a manner of thinking, and sometimes of talking, which may be all but incomprehensible to the lay world. Accordingly, a most important part of the researcher's job is to produce final reports that can be understood by the nonscientist. Good, bad, or indifferent, these reports are the nominal basis upon which his scientific work is judged by the company he works for. Yet the average administrator has neither the time nor the training to make a competent evaluation of scientific methods, thought processes, or experimental designs. As a result, the scientific staff must have an outlet, outside the company, through which true professional status can be achieved in recognition by scientists of at least the same competence as the ones who do the work.

One means of providing such an outlet is through publication and attendance at scientific meetings. The general policy in industrial research is to promote such activity to the fullest possible extent (Appendix 5). As Norman Shepard, Chemical Director, American Cyanamid Company, wrote (1945)

It almost goes without saying that a liberal company policy on publication and presentation of scientific papers is essential to the happiness and, therefore, to the efficiency of research workers.

In addition to increasing productive efficiency through higher morale, there are several good reasons that scientific personnel should be urged

> . . . to keep up with their fields and to add to their professional stature by attending meetings of professional societies and writing and delivering technical papers (Orth, 1959).

Robert E. Wilson (1949—Standard Oil of Indiana) says: "It is not just a matter of humoring the man, but can usually be justified from the company viewpoint." For example, one of the duties of the Director of Research, as shown in the Organization Guide of the Owens-Illinois Company, is

> To enhance the Company's technical reputation wherever possible by the publication of general or non-confidential technical information developed in our laboratories.

and Maurice Holland (1959—Research Consultant) lists

> Scientific papers published or presented at technical meetings as one measure of the research prestige of the company.

In industry, research prestige can be important for two reasons. According to Dr. Ira H. Abbott, Director of Advanced Research Programs for the National Aeronautics and Space Administration (1961)

> The importance of prestige is, perhaps, most apparent in recruiting. With sufficient prestige, it can be assumed that the man sought will know about the reputation of the organization and will be favorably inclined toward employment there as compared to other places which are relatively unknown.

And, second, research prestige can be of considerable value in establishing and maintaining a desirable "public image".

In resource work, the recruiting value of prestige may be of minor significance—particularly at the state level, where virtually prohibitive residence requirements can make it impossible to select personnel from the best in the field. It is nevertheless true that organizations with good reputations attract the best men.

> And the reputation of the Laboratories is nothing more than the sum of the reputations of its individual employees (Bell Telephone).

Further, where a good reputation has been earned, there will be a concerted effort by the employees to maintain that reputation by doing good work.

2. *Professional Freedoms*

One of the basic concepts of research climate was described by the then Secretary of War, Robert P. Patterson, in 1945, when he wrote

> . . . research and development in industry, as in the university, flourish best in an atmosphere of complete freedom; control will wither science by destroying its precious essence of originality and spontaneity.

Dr. Ira H. Abbott (1961—National Aeronautics and Space Administration), in discussing "freedom" as a facet of research atmosphere, listed three general types

1) General freedom in matters unrelated to science, notably political and religious freedom.
2) Freedom to pursue one's natural inclination to work in whatever area of science one wishes.
3) Freedom to pursue scientific inquiries wherever they may lead without encountering dogma dictated by authority.

The latter two types are the ones generally considered important in research administration, and Dr. Abbott says of the first type

> It is difficult . . . to reconcile absolute requirements for this type of freedom with the high quality and productivity of current Russian science. I am forced to conclude that scientists, being people, require this type of freedom neither more nor less than other elements of the population.

A second large group of factors influencing research climate, then, are those relating to the scientific and intellectual independence of the individual scientist. For the purposes of this paper, respondents to the letter of inquiry and those interviewed were asked about the level of autonomy granted research-staff members. As the question was worded, it placed no limit on the professional freedoms which might be included.

One reply, that of V. C. Bartlett, Chief Chemist for the Research and Exploration Department, Ideal Cement Company, is of particular interest. He said "I've never tried to find out"—which, in itself, implies quite a lot about the autonomy of scientists at the Ideal Cement Company. Almost without exception, the research administrators queried recommended a high degree of autonomy for the individual doing research (Appendix 6). Typical replies were those of James B. Austin (U.S. Steel Corporation)

> . . . a fairly high degree of independence is desirable. What we try to do is to pick a man who is interested in a field which we wish to investigate and then to give him a fairly free hand to pick individual projects and carry them out.

R. L. Terrill (Spencer Kellog and Sons, Inc.)

> . . . individual staff members actually carrying on the research should be as autonomous as possible.

And Captain Donald C. Campbell, U.S.N., Director of the Laboratory Management Division, Bureau of Ships

> We endeavor to give good technical people all the freedom possible in organizations concerned with considerable military security and utilizing appropriated funds.

Throughout the literature, similar opinions are expressed. In delivering a joint paper written in collaboration with Dr. DeWitt Stetten, Jr., of the National Institutes of Health, Dr. Charles A. Anderson, Chief of the Minerals Deposits Division, U. S. Geological Survey, said (1957)

It is my belief that the greatest return on an investment in the support of research will be realized if mature scientists are given, within reason, such support as they may require and are then told to do what they please.

a. Planning of Work

In more specific terms, Webster defines autonomy as the "right of self-government". Applied to research workers, this covers a wide range of factors from the degree to which the individual scientist plans his own work to self-determination in such matters as working hours and working habits. Probably the most important of the factors included is that each scientist be allowed to determine his own methods of attacking a problem. Statements of the Vice Presidents of two large industrial laboratories will demonstrate the policies of these organizations. In 1947, Reginald Jones, Bell Telephone Laboratories, wrote "The charting of the paths to their achievement is properly left to key workers themselves"; and eleven years later, James Hillier of the R.C.A. Laboratories wrote "The creative individual must have freedom of action within his field of interest."

The creative spark, at least as it is understood at the present time, cannot be fanned to flame except in an atmosphere of free choice. Dr. Herbert A. Shepard, Professor of Behavioral Sciences at the Case Institute of Technology (1959), explains this phenomenon in terms of the "umweg" principle of Gestalt psychology. He generalizes as follows.

. . . the more you want something, the less likely you are to be able to think of more than one approach to it. Umweg phenomena can readily be demonstrated by putting grains of corn on one side of a fence six feet long, and a chicken on the other side, opposite the corn. The chicken tries frantically to get through the fence to the corn instead of going round the end. It is only when the chicken becomes so distraught that it begins to pace the floor that it accidentally finds the end of the fence.

Dr. Shepard recognizes that ". . . it is not permissible to generalize from the uncreativity of chickens . . .", but he suggests that in scientific research the creativity of researchers is greater where they are allowed to follow their own tangent of investigation — even if it is obviously a detour rather than a direct approach. Norman Shepard believes this to be so important that he recommends the scientist be allowed to fail and start over on all but the longest detours, rather than be forced to take an "obvious" approach (1945—American Cyanamid Co.).

b. Selection of Problems

In addition to charting their own investigative methods, it is a generally accepted practice in industry that scientists actually select their own problems. James B. Fisk, President of the Bell Telephone Laboratories, says (1959)

Important elements of a research environment are certain freedoms. Freedom in the choice of problems—subject to the criterion of relevance.

And L. R. Buzan, Assistant Head of Administrative Engineering for the Research Laboratories of the General Motors Technical Center, writes

> . . . if a man suggests there is an information void in some field . . ., and evidences an interest in exploring this area, he likely will be permitted to do so . . .

At the High Altitude Observatory of the University of Colorado, the staff scientists

> . . . were chosen for their abilities as independent, creative research people. They pursue research problems of their own choosing, and, although the director keeps in close touch with their work, he does not specify the direction that it should take (Andrews).

There are several reasons for this practice, but three seem fairly obvious. First, there is the relationship between research creativity and the confidence displayed by administration. If research problems seem always to come from the top down, the research scientist has little alternative to the assumption that management does not trust his judgment or abilities.

Second is the psychological relationship between interest and creativity. Charles Orth, 3rd (1959), in *Harvard Business Review*, says that one of the ". . . basic elements of the climate for creative research" is that

> Work assignments of real interest (be given) to scientists on the professional staff.

Of course, the scientist may be extremely interested in a problem which has come down from administration, *but* if he is not, the problem will likely remain unsolved. For, as Reginald Jones (1947—Bell Telephone Laboratories) points out

> Ideas cannot be produced to order. They come through inspiration and not by command.

Finally, it is not uncommon that the problems suggested by management are more closely related to "fire-fighting" than research. It is the general consensus among industrial research organizations that the research staff should enjoy freedom from "trouble-shooting." George Beal, Assistant Director of the Mellon Institute of Industrial Research (1943) lists, as one of the reasons that research and management should be completely separated, ". . . that technical men won't be assigned to management emergencies"; and the Booz, Allen, and Hamilton survey of 100 companies successful in research (Randle, 1959) found that one of the critical problems was "research dilution"—including the diversion of research personnel to nonresearch assignments.

In those situations where research people do handle management emergencies, some special situation is involved. The usual case is where the industry is only a step behind research, and everyday problems are actually research problems, too. Another is that described by David C. Lea, Director, Research and Development, Ecusta Paper Division of Olin Mathieson Chemical Corporation, wherein such problems provide a part of the educational experience for research personnel.

> As a matter of fact, we make all experimental mill trials and do considerable trouble-shooting. The time and money expended in this direction are not charged against our Research budget but doing these things does occupy considerable of our Research personnel's time. In the fields of interest that we have, I do not consider this an unfavorable situation in that our Research people become very knowledgeable with regard to pulping, papermaking and converting problems.[1]

If a plan of this nature is used, the administrator should be very certain that the emergencies covered actually do give valuable experience to his research people. Even then, as Colonel Leslie Simon, Director of the Ordnance Department Ballistic Research Laboratories (1947), points out in a list of recommendations to the War Department on the conditions which foster research, the volume of service work should be small, and when it begins to interfere with research it should be transferred to the service involved. In the long run, most administrators agree with Westbrook Steele (1945).

> I do not believe that research . . . can be expected to be the answer to a crisis. But it can and will provide the foundation for sound progress.

Obviously, the manner of selecting problems cannot be determined by a hard-and-fast rule. Management must have some control over the direction research takes, and any research scientist should expect the veto of problem suggestions which are not relevant to the business or will exceed the financial capabilities of the organization. Good communications, in both directions, will usually provide an answer. The Union Carbide Corporation, for example, uses a Research Committee to determine the direction research will take. Dr. Raymond W. McNamee, Union Carbide's Manager of Research Administration (1958), says

> The proposals come from the young scientists. They are screened by their own laboratory managements and submitted to the Research Committee for approval.

Further, there is usually some relationship between the experience of the scientist and the method of selecting a problem. In the case of a new man, fresh out of school, it is often better to assign a problem, because that is probably the way he received his problem for graduate study. Dr. W. D. Lewis, Director of Switching Research for the Bell Telephone Laboratories (1957), wrote

> We have found by experience that new Ph.D.'s are usually happier and more creative if they start to work on a problem chosen by management than if they are asked to select one for themselves.

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[1] Note, however, that the expenses involved are not charged against research and that the number of research people available is apparently based on the premise that some emergency work will be handled.

c. Administration

Other important factors classed as professional freedoms can mostly be related to working habits imposed by organizational structures and administrative requirements. Dr. Kenneth Davis of the University of Michigan (1960) writes "Traditionally and habitually, scientists distrust 'administration' ", and Drucker (1952) lists "the administrative process" as one of the major friction points between management and professional people. He points out, in *Harvard Business Review*, that the most commonly accepted administrative organization is based on supervision

> . . . because it is the established thing for other employees. Yet not only is it resented by professional people; it is not the appropriate organization pattern for them.

One of the major reasons it is not appropriate has been suggested by James Hillier (1958—R.C.A. Laboratories).

> The research management must recognize that nonconformity often accompanies creative ability and must be willing to accept and work with the personnel problems that may arise as a result of nonconformity. The creative man continually challenges the interpretations of the rules of nature. The interpretations of man-made rules are even less acceptable without questioning.

In analyzing the influences of administrative rules, Charles Orth, 3rd (1959), finds that

> Scientists and engineers cannot or will not (and is there a practical difference?) operate at the peak of their creative potential in an atmosphere that puts pressures on them to conform to organizational requirements which they do not understand or believe necessary.

But what are the facets of administration that seem unnecessary to the researcher? Orth provides a fairly good general description in one of his ". . . basic elements of the climate for creative research." He says

> . . . The manager should refuse to impose rules and regulations on the professional staff which imply their lack of intelligence, maturity, or understanding.

Specific examples can be cited. Some of them can be classed as petty administrative rulings related to the use of time. Administrators should realize that the competent research scientist has spent a minimum of four years, and probably longer, determining his own course of action in the conduct of a collegiate program. Such a man appreciates the attitude expressed by Mervin J. Kelly, President of the Bell Telephone Laboratories (1957).

> Compliance with standard working hours is not stressed. The men of research are free to do their studying and contemplation at home.

It must be obvious, as Dr. W. D. Lewis of the Bell Laboratories (1957) has said, that "A creative mind does not stop working at five o'clock." Accordingly

> Punching of time-clocks, pettiness relative to time off, insistence on continuous experimental work, frowning on the reading of technical or scientific journals during working hours or criticism for apparently doing nothing but look out the window—pettiness of any kind on the part of management—incenses research men, notwithstanding the fact that pettiness is unfortunately a characteristic of even some very high-grade investigators. (Shepard, 1945—American Cyanamid).

In industrial research, there has been a concerted effort to avoid conflict over this point in the research laboratory. According to Boehm (1957), Vice President Laurence Hafstad of the General Motors Research Center

> . . . lets his men come and go pretty much as they please. The result, he suspects, separates the men from the boys; "The good people work better, and the weak ones get worse."

This tendency toward freedom in the use of time is so strong that many industrial organizations actually expect their men to use a portion of their time working on projects not related to their assigned work. For example, Dr. J. W. Copenhaver, Director of the Central Research Department at Minnesota Mining and Manufacturing Company, writes

> All of our research people are encouraged to use up to 15% of their time to work on their own ideas rather than on formally assigned projects.

And Boehm (1957) has noted that

> Almost every large industrial laboratory . . . is now encouraging its scientists to spend from 5 to 20 per cent of their time working on projects of their own choosing.

Other forms of unnecessary administrative rulings can mostly be classified as "petty red tape." These can take many forms. For example, Norman Shepard, Chemical Director, American Cyanamid Company (1945) mentions a ridiculous ruling requiring a research chemist to fill out a withdrawal slip, in triplicate, to obtain a bottle of reagent from the stock room. Another example is implied by Colonel Simon (1947). He suggests in his recommendations to the War Department that government bidding and purchase regulations be relaxed for research. When a specific piece of equipment is ordered, it is extremely frustrating to have an in-inferior item substituted by the purchasing division. In addition, the delays attendant to obtaining complete specifications and several bids may actually result in the loss of data or of the whole experiment. This is true in any kind of research, but it is particularly true in the ecological and vegetation analysis studies which so often form a part of resource research.

3. *Other Factors in Research Atmosphere*

Factors of a nonprofessional nature in research atmosphere can mostly be related to conditions which affect the morale, well-being, and contentment of the scientific worker. Such considerations do not usually receive active scrutiny by administrators and personnel officers associated with management and production, but they can be extremely important in research. At first glance, these considerations seem to amount to overt pampering of the employee; and, taken out of context, some of the literature borders on the absurd. Nevertheless, a nearly overwhelming mass of evidence from industrial research experience and from studies of the psychology of creativity have established that happiness and high morale are virtually prerequisite to maximum creative effort.

a. Residential Environment

The gamut of conditions which industrial research administrators consider in this respect may even include the residential environment. Not all administrators agree on the importance of this factor, but the following quotations from a brochure describing Palos Verdes Research Park, a development of Great Lakes Properties, Inc., of Rolling Hills, California, will illustrate one view of the question.

> To attract and hold key personnel advanced-thinking companies are locating their research facilities in suburban communities which provide ideal living conditions. The location of properly planned research parks in suburban, campus-like environments is stimulating to creative minds and provides the logical answer to this trend.
> Palos Verdes Research Park is based on sound principle and planning considerations determined only after comprehensive studies by the Stanford Research Institute and Victor Gruen Associates.

That this is not the isolated view of a real estate promoter is indicated by the following excerpt from "Your Career in Science and Engineering", a booklet published by the Bell Telephone Laboratories.

> Famous stores, concert halls, museums, and theaters are all near enough for an "evening in the city" or day's excursion. Sailing or fishing along the New Jersey coast is conveniently close for holidays and weekends. Lakes and resorts abound, as do famous historical landmarks and preserves. The area is also a convenient starting-point for vacation trips to the New Jersey or Long Island shore . . .

It is also indicated by this, from "You and the Forest Products Laboratory".

> Madison offers unique opportunities for outdoor recreation on an all-year basis—partly due to its location on an isthmus between beautiful Lakes Mendota and Monona. In season the Madisonian has recourse to swimming, boating, fishing, water skiing, skating, winter skiing, . . .

And, third, it is indicated by this, from a brochure intended to attract scientists to the Central Radio Propagation Laboratory of the National Bureau of Standards.

> An incorporated city with a population near the 40,000 mark, Boulder lies at the very foot of the front ranges of the Rocky Mountains. Its elevation is 5,345 feet, the humidity low, the climate invigorating. Rainfall averages 18.3 inches annually; and the sun shines some 300 days every year.

The obvious rebuttal to this view is provided by Dr. Ira H. Abbott, Director of Advanced Research Programs for the National Aeronautics and Space Administration (1961). He points out that

> High quality scientific work is being accomplished today in the middle of deserts, in ordinary office buildings in the hearts of big cities, in small towns lacking the cultural advantages of cities, and in industrial-type buildings along side the railroad tracks. I think it apparent that the presence or absence of . . . other environmental factors . . . are considered far more important by most scientists than the physical environment. Here again, however, we should remember that scientists are people and that some of them will consider the physical environment to be the most important factor. If management deliberately sets out to attract this type, I think it should also be prepared to take whatever measures are necessary to convince such people that they are not living on a continuous paid vacation.

b. Physical Facilities

Whatever their opinions concerning the residential environment as a facet of research atmosphere, research administrators do seem to agree on the importance of physical facilities. For example, Darol Froman, Technical Associate Director of the Los Alamos Scientific Laboratory, wrote

> As for atmosphere, items of importance are . . . providing adequate research facilities, equipment, etc. . . .

and Norman Shepard (1945—American Cyanamid) says "It is false economy to haggle about the cost of providing such equipment." For, in the long run, any investment in good facilities and equipment will pay off in better research. Mervin J. Kelly (1957) observed, after the Bell Telephone Laboratories had moved to new quarters

> Certainly it has been the experience of our Laboratories that the new functional buildings and the generous supply of technical facilities have greatly increased the effectiveness of our research and development work.

c. Educational Encouragement

Another factor, and one which can have immediate effect on morale and productivity, concerns educational advancement (Appendix 7). Colonel Simon (1947), in his list of conditions which foster research, says ". . . formal education, by subsidy or time off, should be encouraged." Nearly all industrial research organizations have some provision for advanced or postgraduate study. The policy may range from simply granting a leave of absence to actual subsidization. The Bell Telephone Laboratories, which may be considered something of a paragon in this respect, have several plans through which their employees may receive additional training. One of these, as described by President Mervin J. Kelly (1957a), requires all four-year engineering graduates to

> . . . devote almost half of their first three years to graduate courses in science and mathematics. Their compensation progress is the same

> as it would be if their full time was spent in the work of the Laboratories.

This program costs Bell Telephone approximately $15,000 per man, and President Kelly says, "We consider it a good investment." Another plan is described in "Your Career in Science and Engineering", a publication of the Bell Telephone Laboratories.

> . . . the laboratories offers an opportunity for employees at all locations to do graduate work at nearby universities under its Graduate Study Plan. Full tuition is paid, and employees may be granted up to 7½ hours per week of normal working time for such studies where necessary.

Among governmental laboratories, similar plans are rarely as beneficent, but they do exist. For example, the National Bureau of Standards Laboratories have a quite liberal arrangement. The Laboratories Director, Dr. F. W. Brown, says that educational leave can be granted under almost any circumstances. If the proposed study program is of particular value to the Laboratories, it is often possible to obtain subsidies covering tuition at the University of Colorado or total expenses at other institutions. And, finally, the Laboratories have a working agreement with the University by which senior staff scientists teach classes in their specialties. Junior staff members receive tuition-free credit, the senior staff attains University faculty status, and the University obtains the use of some of the best research men in the field.

No matter what method is used, the company seems always to benefit out of proportion to its actual contribution. Norman Shepard of American Cyanamid (1945) believes

> This is worth all it costs and is highly appreciated and certainly increases the efficiency of the man who undertakes it.

And, even if a man never takes advantage of the opportunities the company has to offer, there is considerable evidence that the *existence* of such an opportunity will increase the loyalty and creative abilities of nonparticipants.

d. Professional Colleagues

Finally, both Simon (1947) and Orth (1959) list association with colleagues of high professional stature as important to research atmosphere. One of the duties of the director of research, according to job descriptions of the Cutter laboratories, is to ". . . provide stimulating professional contacts for the men when possible." Again, the reason for such recommendation can probably be found in the psychology of creativity. James Hillier, Vice President of the RCA Laboratories (1958), points out that

> A continuing stream of accomplishments in the environment appears to be highly stimulating to the individual.

Association with men who have done and are doing high-level, creative work can provide this kind of stimulation.

Unfortunately, this is not an easy problem for the research administrator to handle. Even in an industrial laboratory with several thousand employees, it is rarely possible to find more than a handful of nationally recognized, top-grade research scientists. For a smaller organization, the maintenance of such a scientific staff may be prohibitively expensive or physically impossible. The answer, then, must lie outside the company staff. Attendance at professional and technical meetings has already been discussed. Other recommendations which have been made include:

1. Temporary appointment to the staff of scientists from other organizations. These men will not become a permanent part of the research staff, but during their appointment they will add much in the way of new thought (Simon, 1947).

2. Temporary assignment of staff members to other organizations for the contacts and stimulation they will receive. Drucker (1952) suggests teaching and outside consultation as possibilities in this area.

3. Contacts with other scientific research organizations at their home laboratories. Job descriptions for the research director at Cutter Laboratories suggest that he should provide contacts with members of other ". . . research departments, universities, and clinics."

C. Organization

Notwithstanding the nearly universal agreement that freedom is a basic component of research atmosphere, it is obvious that some organization for research must exist (Appendix 8). Confusion is the end product of anarchy. Dr. Kenneth P. Davis, Chairman of the Department of Forestry, University of Michigan (1960), observes that

> Research costs money and a lot of it, and except in the universities, is mostly financed by the public or by organizations who definitely expect to get something useful out of the investment.

And Dr. Harold Gershinowitz, President of the Shell Development Company (1960), believes

> Organization is necessary for the welfare of the creative worker. Organization is needed to provide the worker with the physical environment, facilities, and material he requires. Organization is also needed to provide the research man with mechanisms for bringing his achievements and requirements to the attention of those who can appreciate them and do something about them.

The problem is not so much a question of the necessity for organization as it is a determination of the type best suited to efficiency in research. Industrial research has made considerably more progress in this area than resource research, but it is extremely significant that there are as many references to the kinds of errors which can be made as there are to positive results. With minor editorial changes, the typical and most common error has been described by Dr. Herbert A. Shepard, Research Associate of the Esso Standard Oil Company (1958).

> The relatively weak position of research and development (sections) of many firms is reflected in their acceptance of the organizational traditions of the rest of the firm, even though these traditions are adapted to the requirements of (management) rather than research. Until recently, few (research sections) have abandoned the organizational model suited for efficient repetition of operations and sought a model more in keeping with the requirements of innovation or the mobilization of intelligence.

This problem has not really been solved. The reason, possibly, is that no one has yet advanced an organizational model which really covers the basic needs of research. Dr. Gershinowitz points out that the objective of all organizations, management or research, is

> . . . to make more efficient the operations they hold together. The difference lies in what constitutes efficiency. Efficiency in most operations can be measured in terms such as unit costs or output per machine or individual, which involve statistical concepts of average salary, average performance, and the like. Perhaps one should stop with the statement that efficiency in most operations can be measured. Efficiency in research cannot yet be measured. If it could be, it would have to be in terms of individual rather than average performance.

There are, however, a number of considerations which influence potential solutions and are discussed in most of the literature of research administration. Underlying all these considerations, and of basic importance, is the fact that research is done by individuals. Dr. Ira Abbott (1961—National Aeronautics and Space Administration), points out that

> . . . each new thought has to originate in a single human brain; other closely associated brains may explore; verify or refute; and expand the thought; but no single, collective brain can be created by management in which the thought can originate.

A basic concept for any research organization, then, is that it should recognize the individuality of researchers. Motivations, incentives, assignments, rewards, working conditions—all the decisions of administration—should be influenced by consideration for the individual scientist. Dr. Gershinowitz (1960) concludes that

> Laboratories vary widely in character but the good ones share the quality of having the organization built to fit the individual research worker. The fit into corporate organization is essential but secondary.

1. *Flexibility*

Possibly the first requirement in designing an organizational structure capable of assimilating the research worker without suppressing his creative abilities is that there be provision for idiosyncrasy as well as talent. Despite a widespread belief to the contrary, there is almost no evidence that scientists, as a group, are any more consistent in motivations and desires than any other group of people. Dr. Abbott makes a special point of the fact

> . . . that research scientists are people. They are, accordingly, subject to all the varied emotions, ambitions, compulsions, dreams, and despairs of the rest of the population, but may be somewhat more expert at rationalizing these basically illogical motivations.

Since there is no stereotype of the scientist, only ". . . a vast array of people doing scientific work . . .", Dr. Abbott believes that for any successful research organization

> . . . flexibility is the watchword. Some scientists, like some donkeys, require the "carrot before the nose and the stick behind the tail" to make progress. Others move well under their own stimulation and react poorly to outside pressures. A wise management will adjust its methods to bring out the best in each man.

2. *Shallow, Informal Administration*

Flexibility of organization can be attained a number of ways, but the most direct is to keep the organization simple. In his opening remarks to the First Conference on the Administration of Research (1947), H. P. Hammond, Dean of the School of Engineering, Pennsylvania State College, suggested

> I should like to sound this note . . . that one of the aims in the administration of research shall be to simplify controls to the greatest possible extent, so that the engineers and scientists can do their work without being unduly hampered.

One method of simplifying controls without losing them entirely is related to the size of the administrative overhead. Commodore H. A. Schade, U.S.N. (1947), observed that

> Any organization after reaching a certain size and, more important, a certain degree of complexity, must resort to a formalization and systematization of its activities which, if unwisely done, can easily stifle the initiative of its individual members. The pall of bureaucracy is always a real danger. This is particularly true in the case of an organization like a research laboratory whose primary function is to further creative endeavor.

And, since bureaucracy thrives best where there is a long, formal order of administrative responsibility, every effort should be made to prevent such an order. Dr. Harold Gershinowitz (1960) says that in the Shell Development Company, ". . . we tend towards the least amount of order that can be steadily maintained short of chaos"; and Dr. R. W. McNamee, Manager of Research for the Union Carbide Corporation, observes that

> . . . in a relatively small research organization the fewer echelons of management responsibility the better. In other words, we believe a shallow organization with a high degree of informality is the most effective.

There is a point, of course, at which formal order becomes an absolute necessity. This point will be different for different types of organizations, but the following passage from Dr. Gershinowitz' paper (1960) suggests that formality probably appears much too early in most resource research organizations.

> It seems to be possible to maintain a loose and informal type of organization until the number of professionals reaches 30 or 40. At that time a departmentalized structure, still fairly loose, becomes necessary. When the professional staff approaches 100, a more formal organization with definite channels of communication and an increase in management levels becomes desirable.

The short chain of command in research has several advantages beyond informality and enhancement of individual initiative. Necessarily, it brings the working scientist closer to top administration and shortens the lines of communication which have such an important influence on research atmosphere. It also allows the scientist to participate in long-range planning and assures that the ideas of younger men will not be lost in "channels". This is important because a number of studies have suggested that creative ability may begin to decline after the age of 40.

Further, a shallow administration assures greater scientific contribution from trained personnel because fewer men are engaged in paperwork, and it allows greater flexibility in channeling research effort. Research of any kind may produce unexpected results, and quite often new lines of investigation appear which are more promising than the original approach. Dr. Richard Kershner, Division Supervisor in the Applied Physics Laboratory at Johns Hopkins University (1957), has pointed out that "A large organization simply moves more slowly" because more memos are needed and more channels must be gone through. The net result, in a large, formal research organization, may be that promising new leads are not followed because too much red tape is involved in abandoning old lines.

Finally, and this is a particularly significant advantage in most civil service systems, a short chain of command allows much greater flexibility in assigning grade levels and pay scales. John H. Farrell, Administrative Officer for the Forest Products Laboratory, Madison, Wisconsin, reports that

> The Forest Service personnel program in research allows excellent leeway for scientific personnel to advance even into super grade levels, based purely upon research ability.

This is possible, according to Dr. Davis (University of Michigan), because the Forest Service has even ". . . gone so far as to do away with a research center leader as such in at least a few instances." Without an overhead of administrative personnel, it becomes possible to raise any scientist at a center to the level formerly occupied by a single administrative leader.

The obvious corollary to the short chain of command, and a factor that has already been mentioned as a facet of research atmosphere, is that the chain should be attached near the top of the organization. Most of the advantages cited here are dependent on such a relationship. Dr. Gershinowitz (1960—Shell Development Company) concludes that

The position of research management in the over-all corporate structure should be such as to provide it with enough information about and voice in policy to make its judgments valid and enough status to make its decisions or recommendations stick.

3. *Organization Charts*

Another theme which appears in nearly all discussions of research organization is related to the creation and existence of organization charts (Appendix 9). A. D. Little has been credited with the statement (Mees and Leermakers, 1950) that "There is a danger in an organization chart—that it be mistaken for an organization." And Norman Shepard, Chemical Director for the American Cyanamid Company (1945), has written that ". . . a hide-bound organization or an over-regimented one, with a sacred organization chart, is a menace . . ."

This is not to say that organization charts are not necessary or useful. It seems particularly true in research, however, that such charts should be used with extreme care and not allowed to dominate personnel. James B. Fisk, President of the Bell Telephone Laboratories (1959), observed

> It is sometimes said that formal organizations and research are not compatible. I do not agree with this. Orderliness in relations among people, smoothness in function, and a free flow of ideas within a conceptual framework are helped, not hindered, by a charting of function and responsibility. But the organization chart must not become master, and organizational position must not be confused with scientific stature.

In research, it is extremely important that scientists dominate the organization chart rather than that they be dominated. In a large organization, charts are an absolute necessity, but even in the largest corporate research groups, such charts rarely present more than a basic outline. Of the dozen or so staffing charts received from such organizations as U. S. Steel, General Electric, and General Motors, only two (Bendix Corporation and the U. S. Navy Electronics Laboratory at San Diego) listed personnel to the project level. In one case, major projects were apparently quite large and included several subprojects. And, in the other, the staffing pattern was actually a complete paymaster's listing of all personnel associated with the organization. Many organizations have no staffing pattern below the laboratory level. James B. Austin, Administrative Vice President, Research and Technology, U. S. Steel Corporation, wrote

> When you get down to smaller groups within each laboratory, I believe you must maintain considerable flexibility of organization and, in fact, in many cases this organization must be built around the men you have available rather than designed to fit some abstract organization chart.

Flexibility in staffing patterns is, in fact, a basic recommendation from several of the administrators contacted. David C. Lea, Director, Research and Development, Ecusta Paper Division of Olin Mathieson Chemical Corporation, observed that

> In a large research department it is easier to fit people into slots than it is in small departments. In the latter, I am almost of the opinion you have to fit various aspects of a research department around the strong researchers that you have available.

and John E. Barkley, Technical Director of the General Mills Electronics Group, wrote

> You should use whatever type of organization structure and staffing pattern . . . seems most applicable to your particular problems, facilities and personalities of key personnel.

4. *Two Promotional Ladders*

Finally, the theme which appears with almost inevitable regularity throughout research administration literature is that standards for promotion should be based on research capability as well as supervisory capacity (Appendix 10). Dr. Herbert A. Shepard, Employee Relations Research Specialist for the Esso Standard Oil Company (1957), has pointed out that promotion for managerial responsibility alone has a doubly deleterious effect on a research organization. First

> . . . it tends to make research workers view one another as competitors for managerial positions rather than as collaborators in scientific work.

And second

> . . . it places the best of its scientific resources in the managerial ladder where most of their energies must be devoted to nonscientific matters.

Yet, it is absolutely necessary, as James B. Fisk (1959—Bell Telephone Laboratories) has pointed out, that

> Within an industrial laboratory every effort . . . be made to insure that salary bears a direct relationship to performance, and that the compensation of professional scientists is competitive with other related opportunities.

The accepted approach to this problem in industrial research is described by E. X. Hallenberg, Director of Administrative Services for the Westinghouse Electric Corporation's Research Laboratories, as follows.

> In many industrial laboratories today, there are two ladders of promotion—one for those who have the administrative managerial responsibility for the technical programs of the laboratory, and another for those whose contribution is primarily technical. Those who make their careers in the nonmanagerial technical areas will receive recognition and pay equivalent to those who make theirs in the managerial areas . . .

a. The Administrative Assistant

As was mentioned earlier, there are two general approaches to the double ladder for promotion. The first assumes the existence of a nontechnical "administrative assistant." This is probably the organizational pattern Charles Orth, 3rd (1959), had in mind when he wrote

> Just as a doctor's income is usually considerably higher than the income of the man who administers the affairs of a hospital, the income of a creative scientist may, and often should be, higher than that of the man who manages the laboratory where he works.

Although this is the least popular of the two variations, the fact that it will work has been demonstrated by the organization of German research during World War II. Colonel Leslie Simon, U.S.A., Director of the Ordnance Department Ballistic Laboratories (1947), found that the research effort which produced the V-2 and laid much of the basic groundwork for current space exploration had nontechnical administrators. He says

> The director of a scientific establishment exercised jurisdiction over the relations between his institutes, looked after such matters for the common good as heat, light, power, guards, fire fighting, and general services and administration, but did not make decisions with regard to scientific affairs of his institutes. The scientific and technical phases of institute matters were under the control of the institute leader.

Colonel Simon believes that the major disadvantages of this system were the lack of coordination and direction, which resulted in duplication of effort and failure to follow some specific promising leads. He even intimates that World War II might have turned out differently if the German research effort had lived up to the potential inherent in its personnel.

Further disadvantages of the administrative assistant center around the personality conflicts which quite often develop. Drucker (1952) points out that personnel administration is often more successful if handled entirely within the research division by research people. Also, there is a general tendency for the morale of the administrative assistant to suffer if he feels he has failed as a scientist (Shepard, 1945—American Cyanamid Company). This is particularly critical in civil service because it is often true. When funds are limited and personnel are protected by certification, the least competent scientist in a group may be assigned the bookkeeping responsibilities—rather than bringing in an administrator from outside research.

Finally, and possibly of overwhelming importance, Dr. Merritt Williamson, Dean of the College of Engineering and Architecture at Pennsylvania State University, points out (1959) that the research and development director must ". . . command the respect of research people." It is true that a nonscientist can do this. Most administrators, however, seem to agree with Dr. Kenneth Davis of the University of Michigan. He writes

> I feel strongly that he must be a professional man in his own right in considerable degree, as otherwise he will never command the respect of his subordinates or have real understanding of what they are doing.

b. The Technical Director

The most widely accepted approach, then, assumes that both promotional ladders include personnel of scientific ability. Using such a system, the Bell Telephone Laboratories have been able to attract and utilize an extremely successful scientific team. According to President Mervin J. Kelly (1957)

> The basic principle is the payment of the individual according to his contribution, while maintaining a Laboratories position well up into the upper 20 per cent of the large industrial laboratories.

Advancement is the same

> . . . regardless of whether the staff member is working in a scientific or technological field, or has assumed management duties. Equally able scientists and engineers in both fields receive comparable salaries. (Bell Telephone).

Descriptions of titles, qualifications, and duties associated with each promotional ladder are available from several sources. Dr. Herbert A. Shepard (1958—Esso Standard Oil) has suggested the following:

Managerial Ladder	*Technical Ladder*
Department Head	Scientific Adviser (reports to top management)
Section Head	Senior Research Associate (reports to Department Head)
Group Leader	Research Associate (reports to Section Head)

Another series for the technical ladder was proposed by Rubey (1931) in *Industrial Organization.* It has only three steps instead of the four implied by Dr. Shepard. At the lowest level are the

> *Assistants:* These are ". . . college graduates who do routine work." In general, they ". . . are ambitious and will work for only a few years in this capacity. Provision must be made for their replacement or promotion."

The next higher level he calls

> *Juniors:* These may come ". . . from the assistants or from university graduates with masters' or doctors' degrees. They, too, are content for only a few years in this grade."

And the highest rank he calls

> *Seniors:* These men ". . . require high scientific ability and research experience." They ". . . must carry sufficient remuneration both financial and professional, to make this part of the personnel permanent."

A third example, and one which is actually in use at the Owens-Illinois Technical Center, has five classified steps and a sixth step based on specific consideration by the Board of Directors. Duties and qualifications are as follows.

Step I: Includes beginning technical people. Requirements are a B.S. degree or 1-2 years of college and 1-3 years of experience.

Step II: Includes technicians and younger scientists who are responsible for independent solution of parts of projects. Requirements are a B.S. degree and 1-3 years of experience or 1-2 years of college and 3-5 years of experience.

Step III: Includes group or section leaders and scientists doing highly competent independent research. Requirements are a B.S. degree and 5-7 years experience or the M.S. and 3-5 years experience.

Step IV: Includes subsection heads and scientists who are recognized authorities in their field within the company. Requirements are an M.S. degree and 5-7 years experience or the Ph.D. and 3-5 years of experience.

Step V: Includes the assistant heads and chiefs of sections and scientists who, if they have no administrative authority, are nationally recognized in their field. Requirements include an M.S. degree and 7-10 years experience or the Ph.D. and 5-7 years of experience.

Step VI: Higher positions are considered specifically by the Board of Directors.

Unfortunately, there are a number of disadvantages associated with this system, too. Most of them can be overcome in the proper environment, but they should be recognized. As summarized from Dr. Shepard (1958—Esso Standard Oil), the major drawbacks include, first, the fact that the technical ladder can be used as a convenient shelf for the incompetent technician. "Relegation of deadwood to the technical ladder destroys its potential value" because the scientific staff will thereby assume that technical appointments are used for punishment and inadequacy. Second, the technical ladder can be hard to identify in the organizational structure. Not only is the feeling of "isolation from the business" (Drucker, 1952) sometimes increased, but the relationship to other positions within the profession may be obscure.

Finally, unless wisely administered, the technical ladder can be a dead end without future. Positions on such a ladder are always less secure because the productivity of a

> . . . scientist in a technical ladder position is more easily assessed, or at least more open for inspection, than the productivity of a manager. Especially if he is doing independent work . . . there is no difficulty in fixing the responsibility on him if his results do not come up to the expectations of management. In evaluating a supervisor or manager, there are many considerations and many areas of irreducible uncertainty (Shepard, 1958).

If this insecurity is combined with a shortage of rungs, a known ceiling on the technical ladder, and a lack of mobility between ladders so that it is not possible to go from the technical ladder to a position in top management, the whole system may break down.

The obvious prescription is wise administration, with particular consideration for personalities and the nonconformity of individuals. If the research director is allowed a wide latitude in handling personnel, his chances for successful operation will be greatly enhanced. For, as Dr. W. D. Lewis, Director of Switching Research for the Bell Telephone Laboratories, has observed (1957)

> Industrial groups based on respect for nonconformity are not only more creative than more conventional groups, but are also more attractive to the highly creative people they most need to attract.

D. Director of Research

The final subject discussed in the literature and mentioned by many research administrators is the research director himself. Much of the material already presented has been suggestive of the director's duties and qualifications. Nevertheless, it seems appropriate to summarize some of the more important segments of the relatively large literature on this single subject.

1. *Qualifications and Duties*

Dr. Merritt A. Williamson, Manager of the Research Division, Burroughs Corporation Research Center (1955), presents the following definition.

> The ideal research executive (research director, research manager, vice-president in charge of research, or whatever title you may wish) may be defined as a person who with maximum effectiveness heads up a group of persons operating with maximum efficiency to produce research results of maximum utility resulting in maximum satisfaction to his employer with minimum expenditure of money.

Dr. Williamson admits that such a personality is probably only a top-management dream. In fact, he compares his ideal research executive to the mythical roc. Unlike the dodo, which became extinct, the roc never really existed—except in human imagination. The "ideal research executive" is a valuable concept, however, because it supplies a basic standard by which research directors may be evaluated and by which individuals may be selected for such positions.

Dr. Williamson continues by pointing out that since no single individual can hope to be all the things suggested by his definition, some parts of the director's responsibility should be delegated. In one way or another

> . . . the office of the director must be in possession of the following abilities; scientific attainment—generation of ideas, administrative ability, and salesmanship.

The various papers, interview and job specifications relating to the Director of Research quite often include long lists of "duties". (Appendix 11). In lieu of attempting to summarize these duties, many of which are repetitive of subjects already discussed, Williamson's three points will be used as subject headings for this presentation. It should be remembered that these headings represent not only the abilities of the director but also of his staff. As Dr. Williamson points out, the director

> . . . may be very weak in certain areas. If he knows what they are he may then surround himself with staff men to supplement these deficiencies.

Many of the ideas presented in this section are not cited to a particular source, but the job outlines and position guides supplied by the General Electric Company Research Laboratory; the Owens-Illinois Technical Center; the Cutter Laboratories; the Office of the Adjutant General, Department of the Army; and the Olin Mathieson Chemical Corporation were particularly helpful. In addition, the papers by Hillier (1958), Williamson (1955), Orth (1959), and Wilson (1949) were extremely valuable.

a. Scientific Attainment—Generation of Ideas

All authorities do not agree, but a possibly basic part of scientific attainment in the office of the director is that the director himself be technically competent. There have been, and are today, successful research organizations headed by nontechnical administrative assistants. Despite this fact, the consensus seems to be that ". . . technical knowledge and skill (and broad research experience) are prerequisite to successful research management" (Shepard, 1945—American Cyanamid).

There are quite a number of reasons for this conclusion. According to Dr. Herbert A. Shepard, Research Associate, Esso Standard Oil (1958), the research director should provide "inspirational leadership." He must also ". . . command the respect of research people" (Williamson, 1959). In addition, one of his important jobs, according to Luis J. A. Villalon, Management Affairs Editor of Research and Engineering Magazine (1955), is to "Advise and counsel management on all technical matters . . ." The separation between research and management is probably greater in industry than in most resource work, but it is still true that the research director may be the only member of the "board of directors" who understands and is sympathetic to research. Among this group, Dr. Shepard (1957) points out that

> . . . he must command faith and trust, perhaps more than any other of the top management group because most members of top management do not understand his work.

Further, the research director is usually responsible for a number of functions which are nominally impossible for an individual with no scientific training. As examples: James B. Austin, Administrative Vice President for Research and Technology, U. S. Steel Corporation, writes

> His major responsibility should include choice of the main areas of work, or, at the least, recommendations as to what these should be.

Dr. M. G. Van Campen, Jr., Vice President for Research, Cutter Laboratories, observes

> It is the research director's job to make sure that projects are continually pointed toward a proper goal and to see that they do not suffer from want of support.

And Dr. J. W. Copenhaver, Director of the Central Research Department, Minnesota Mining and Manufacturing Company, writes that the research director is

> . . . charged with the responsibility for implementing research leading to new and unrelated products and to provide the company with a sound technical foundation for continued growth.

With regard to generation of ideas, the director, according to Luis J. A. Villalon (1955), should "Be something of a dreamer and a visionary . . ." He should be capable of producing ideas of his own, he should be abreast of the latest ideas appearing in the literature of his field, and he should maintain an organization in which all members are free to make suggestions and present ideas. In this respect, it should also be noted that the research director should not—and this point is emphatic with nearly every research administrator and writer—he *should not* impose his ideas on his subordinates except through suggestions—which they may accept or reject as they see fit.

Even the men who are known and recognized authorities in their fields do not expect subordinates to conduct research on a supervised basis (Appendix 12). Dr. LeRoy Powers, Principal Geneticist in charge of the Fort Collins Sugar Crops Section, Tobacco and Sugar Crops Branch, Agricultural Research Service, USDA, says that his philosophy of research administration is to "Hire good men and turn them loose." He does offer advice in some cases where he is technically qualified, but he says that this advice need not necessarily be followed. Similarly, Dr. Vincent Schultz, Ecologist, Environmental Sciences Branch of the Division of Biology and Medicine, U. S. Atomic Energy Commission, writes "Research objectives and procedures are left up to the investigator with some *suggestions* from me." Thus, while the director should have good ideas of his own, his major responsibility, in the words of James Hillier, Vice President of the R.C.A. Laboratories (1958), is

> . . . the selection of creative individuals and the establishment of an environment that maintains their creativity and directs it to the accomplishment of the research objectives.

b. Administrative Ability

Robert E. Wilson (1949—Standard Oil of Indiana) lists, as the first qualification for a director of research, ". . . that he be a good administrator." He considers this even more important than being a "good scientist". Unfortunately, as Dr. Merritt A. Williamson, Dean of the College of Engineering and Architecture, Pennsylvania State University, has pointed out (1959)

> . . . there is a real danger for anyone to accept the cliche that "management is management" and that, therefore, any good skilled manager can be successful in the R. and D. area.

The normal criteria for administrative success are dynamic leadership and a smoothly functioning organization. Yet, Dr. Williamson states that

> . . . one who looks for smooth running as any evidence of good R. and D. management is in my opinion either stupid, inexperienced, or just plain naive.

Actually, he continues, the most effective research director

> . . . may well be . . . quite inefficient. . . . he may run a pretty sloppy office. He may very well meet his appointments irregularly. His desk may be piled high with all sorts of . . . material reflecting a divergence of interest and not a convergence on the narrow task of keeping the desk clear for action. . . . The R. and D. manager . . . will have . . . trouble in delegation. . . . will want to be interrupted at times—particularly if there is a technical problem. He will prefer interruption from those at the lowest level, not the "important" people, . . . he may not always be prompt in sending documents to the outer office for filing. . . . He is keenly sensitive to the undesirability of being interrupted by executives who are over him and he does not intend to inflict interruptions on those below him if he can help it. In fact, he is probably apt to go too far in this regard . . . he will take the highly inefficient action of finding others wherever they may be and however long it may take to locate them. . . . on a number of occasions his secretary may not know where to locate him. . . . As to being dynamic, decisive, and clear cut, this is one of the worst traits . . . for any R. and D. manager.

The point Dr. Williamson makes is that inefficiency, in the areas indicated, may be the most effective administration because it helps to create an aura of ". . . understanding which is the key to greatest productivity when one is dealing with creative persons."

This is not to say that dynamic efficiency is undesirable. It just underscores the fact that research administration places its major emphasis in areas other than decision-making. Captain Donald C. Campbell, U.S.N., Director of the Laboratory Management Division, Bureau of Ships, points out that

> The important function of the R. and D. organization is to enhance and make best use of the capabilities and human characteristics of its staff.

And Darol Froman, Technical Associate Director of the Los Alamos Scientific Laboratory, writes

> My personal impressions are that the most important and effective activity of a research director is to provide an atmosphere conducive to high-quality research, and to ensure that the staff selected are well-trained, intelligent and enthusiatic people.

Accordingly, administration, in the sense usually applied to research management, is the ability to recognize creative people and to manipulate working conditions, not personnel, so as to obtain the greatest possible scientific contribution. When personnel are taken from civil service registers, the director may be extremely limited in the selection prerogative, but there are a number of areas in which he can have an influence on working conditions. Many have already been mentioned in the discussion of research atmosphere. Others can generally be considered to revolve around leadership and around coordination and planning.

(1) *Leadership*

Robert Kennedy Duncan, the founder of the Industrial Fellowship system, has said, "Whoever will be chief among you, let him be your servant." (Weidlein and Hamor, 1936). In a single sentence, this may be the best possible description of the leadership qualities necessary in a director of research. Areas in which the director can demonstrate effective leadership are, first, the formulation of long-range objectives and policy for research. All scientific personnel should participate in the basic formulation of policy and objectives, but the research director is the man who must carry the ball to top management and obtain realistic, understanding acceptance. To a great extent, the confidence management displays in research can be influenced by the leadership of the research director.

Second, the research director should serve as the main line of communications between the working scientists and the rest of the organization. His leadership in this area includes keeping an open channel to top management and in maintaining ". . . communication between his group and other parts of the laboratory and the company . . ." (Hillier, 1958). In addition, his leadership should be demonstrated, according to job specifications of the Owen-Illinois Technical Center, in the administration of

> . . . corporate policies with respect to scientists in the way most probable to motivate and inspire effective and creative research activities.

In this respect, he

> . . . should insist on consulting with professional workers about plans or proposals which will affect them and/or their work before decisions are made. (Orth, 1959)

Third, the R. and D. manager serves as a buffer between management and research people. Research, because it is not easily evaluated in terms of over-all company objectives, may sometimes receive unjust or unthinking criticism from top-management or other sources. The research director should be responsible for assuring that chance, or even well-meaning, actions and remarks do not affect the creative potential of his staff. Dr. C. E. K. Mees, Vice President in Charge of Research, Eastman Kodak Company, has said (1945—in Discussion after Midgley)

> No director who is any good ever really directs any research. What he does is protect the research men from the people who want to direct them and who don't know anything about it.

There are several ways in which the research director can act to prevent nonscientists from unnecessarily interfering with the scientific staff. He should make every effort to explain current projects and progress to management so they will understand what is going on in the laboratory. He should be responsible for continuous evaluation of all projects, and he should bear the responsibility for deciding when certain lines of investigation should be pressed or abandoned. Finally, he should "Keep his department in line with company policies . . ." (Villalon, 1955). This may sometimes be an extremely hard objective, but if company policy has been wisely stated and is broad enough to include the special conditions which encourage creativity, it can be done.

Finally, the research director is responsible for stimulation of scientific personnel. His leadership in this area can be demonstrated by encouraging various types of professional contacts, by encouraging presentation of scientific papers and attendance at professional meetings, and by channeling interesting papers to proper members of the staff. In short, the research director should always be concerned with the professional upgrading of his staff. For, as Dr. Williamson (1955—Burroughs Corporation) has said, "This is absolutely essential if the research division is to have continued vitality."

(2) *Coordination and Planning*

Administrative abilities of the director of research are particularly important in those areas which involve coordination of current effort and long-range planning. And, based on the number of people who mention it (Austin—U. S. Steel; Bartlett—Ideal Cement; Brown—National Bureau of Standards; Copenhaver—Minnesota Mining and Manufacturing; Powers—Agricultural Research Service, USDA; and many others), administration of the budget is the single most important facet of this work. As a general rule, industrial research directors are responsible for preparing the budget, administering its control, and for anticipating new facilities and assuring that they are available when needed. According to G. H. Young, Assistant Director of the Mellon Institute of Industrial Research (1947), one of five basic principles

> . . . in sound administration of project-organized research is the accurate forecasting of probable costs in expendable materials, men and money, and *provision in advance,* of funds upon which the researcher may draw *when needed,* not at some unpredictable future date after "board approval", or other frustrating and disheartening delays so deadly to the research temperament.

Other important areas of planning include the long-range prediction of research objectives and the anticipation of new fields of investigation. In this respect, the research director is also responsible for continuous evaluation of project work and recommendations relating to the initiation of new projects and the abandonment of old ones.

Finally, the research director is responsible for scheduling the use of manpower and equipment to obtain the greatest possible benefit for the company. It is an accepted policy in industrial research that ". . . operational and repetitive details . . ." should be delegated

> . . . in order to free the time of valuable scientific personnel so that they can carry out their work unhampered by troublesome routine. (Williamson, 1955—Burroughs Corporation)

This means that a significant part of the personnel in any research organization will be technicians, laboratory assistants, and secretaries. Proper scheduling by the director of research will assure that no scientist ever wants for such help and that full utilization is made of all available personnel.

c. Salesmanship

The third ability which must be available in the office of the director of research, if not in the director himself, is the ability to demonstrate research accomplishments and values. Maurice Holland, Industrial Research Advisor (1947), lists several ways in which research can aid the company through good salesmanship. He says

> Research should dramatize the company's progressive position in its industry with periodic announcements, demonstrations, and exhibits of new product developments, provide factual copy of technological advances for sales promotion, stockholder literature, advertising, and technical public relations to the industrial and lay press.

These things are important, and they may entail the use of the director of research in a public relations capacity—possibly more than either the company or the director will desire.

More important, however, is the handling of intra-company relationships. Mr. Holland goes on to say

> The biggest single public relations problem which *any research laboratory* has, is in selling *itself* to its own *company.*

This bears repetition, because the whole success of any research organization may hinge on this single point. Behind this statement lie most of the factors inherent to obtaining and keeping the best in scientific personnel, many of the problems of maintaining a creative atmosphere in which they can work, the majority of problems in obtaining funds and adequate facilities, and, in fact, one of the basic measures of the success of the director of research.

In case this description suggests the "hard sell" technique, it should be noted that such an approach is not necessarily recommended. The point that most writers make is that top management cannot be expected to extend whole-hearted support to an activity they do not understand. Staff scientists should produce final reports which are understandable, but the day-to-day justification for the existence of research is a duty of the director. Progress in research is often slow, and while patience is a basic attribute of the scientist, it can be expected to wear thin in the men who must furnish the money.

If these men know what is going on, through continuous briefing by the director, they can be expected to demonstrate the confidence and patience every successful research organization generates.

2. *Research by the Director*

One of the specific questions in my letter of inquiry related to the amount of personal research conducted by the director of research. Not too surprisingly, since many of the industrial organizations included in this survey have research laboratories involving 1,000 or more people, the majority of replies indicated that administrative duties prevent such activity (Appendix 13). In fact, James B. Austin, Administrative Vice President, Research and Technology, U. S. Steel Corporation, pointed out that

> Not only is he too busy with general laboratory administration but if he attempts to do research himself he may get into competition with some other members of his staff which can lead to difficulties.

Many of the directors, however, indicated, like David C. Lea, Director, Research and Development, Ecusta Paper Division of Olin Mathieson Chemical Corporation, that

> . . . they would like very much to be able to spend some time in actual research but, as a practical matter, . . . find it impossible to do so.

There are exceptions. One specific example was provided by E. X. Hallenberg of the Westinghouse Electric Corporation Research Laboratories, who writes

> Normally, a Director of the Research Laboratories the size of ours is not engaged in personal research. Our Director, Dr. Zener, contrary to the normal practice, engages a portion of his time on technical and research matters.

And, Mrs. Mary L. Andrews, Assistant to Dr. Walter Orr Roberts, Director of the University of Colorado High Altitude Observatory, writes

> It is Dr. Roberts' strong feeling that the director of a scientific research program should be himself a scientist doing active research work.

Possibly, the determining factor in this respect is the size of the organization. R. H. McFee, Director of Research at the Azusa Plant of the Aerojet-General Corporation, suggests, "If the research group is a large one, the director will find it very difficult to get time to carry out his own investigations." On the other hand, in a small organization, the director can probably conduct considerable research of his own. Dr. LeRoy Powers, Principal Geneticist in Charge of the Fort Collins Sugar Crops Section of the Tobacco and Sugar Crops Branch, Agricultural Research Service, says that the determining factor is usually a really *good* secretary. Such a person, after proper training, can make many of the day-to-day decisions, handle visitors and salesmen, and, in short, free the director from some of the administrative duties which prevent utilization of his scientific abilities.

IV. CONCLUSION—A MODEL FOR RESOURCE RESEARCH

The apparent conclusion for a review of administrative methods should be presentation of a model organization plan, staffing pattern and administrative policy. However, if this review makes any point obvious, it underscores the fact that no definitive model could be realistic for research. Presentation of a specific plan would defeat the purpose of this study, because research administration, more than any other form of personnel management, must deal with people as individuals. It is not realistic to describe a norm when creative endeavor is dependent on divergence from the norm.

In lieu of a specific plan for resource research, the principles involved in research administration can be related to those involved in personnel administration for management and production by comparing a pair of models (Fig. 1). Differences between these models are almost entirely

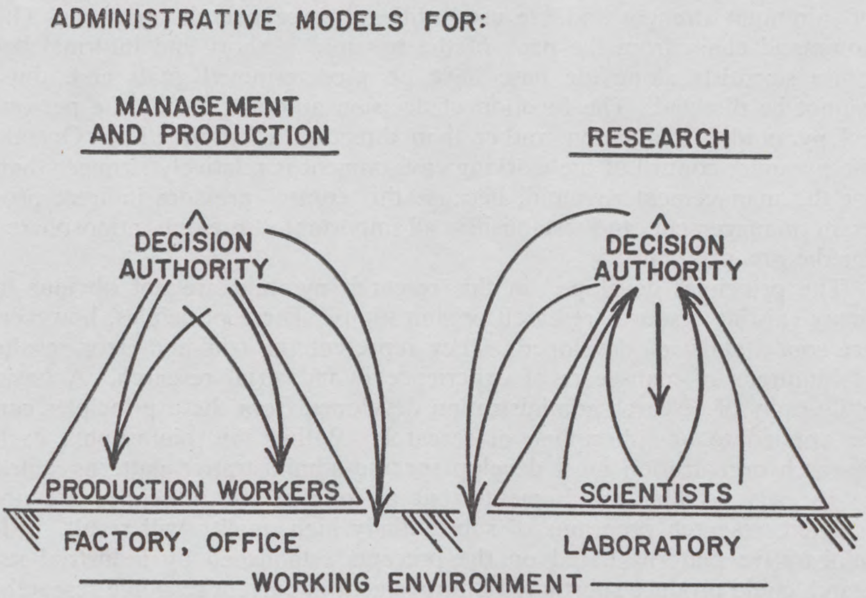

FIG. 1. Administrative models for management and production vs. research.

due to the fact that output in research is measured in terms of ideas created by individuals, while output in management and production is measured in terms of work units handled or created by a group. For each model, the total working force is represented as a pyramid, with the authority for decisions at the peak and the production units—clerks, laborers or scientists—at the base. The platform supporting either pyramid is the working environment—laboratory, factory or office.

Within the management and production pyramid, the primary principle of administration is to insure control. Decision authority maintains communication as a means of dispensing directives. Lines of communication flow downward within the pyramid to personnel and outside the pyramid to the working environment. Every part of a typical organization based on these principles is designed to provide smooth function. The production units in the base are expected to achieve predetermined goals in both quantity and quality, and their efforts are directed through a chain of command linked directly to the peak of the personnel pyramid. These principles are well established and can be recognized in patterns ranging from the essentially straight-line organizations of military field units to the line-and-staff organizations of most corporations and resource-management agencies.

Within the research pyramid, the primary principle of administration is to encourage creativity. As in the management pyramid, communication lines are linked directly to the peak, but the major flow is upward. Decision authority must communicate to prevent chaos, but directives are of minimum strength and are used only to shape overall programs. The command chain from the peak of the pyramid is short and informal because scientists along the base have no predetermined goals and, thus, cannot be directed. The function of decision authority inside the personnel pyramid is evaluation, rather than direction, of production. Outside the pyramid, control of the working environment is relatively stronger than for the management pyramid, because this control provides indirect program management and establishes all-important "research atmosphere" for the organization.

The principles developed in this research pyramid are not obvious in many existing resource research organizations. These principles, however, are sound and well-developed. They represent the trial-and-error results of hundreds of man-years of experience in industrial research. A basic philosophy of research administration developed from these principles can be applied to any discipline of research. Within this philosophy, each research organization must develop specific administrative patterns suited to its own peculiar requirements, but as long as the principles are not violated, research programs of substantially high quality will result. Administrative patterns based on the precepts established by industrial research could produce substantial improvement in current resource research.

SUMMARY

Resource managers have not paid as much attention as they might to the progress in research administration being made by industrial organizations. Industry has tested methods which represent radical departures from accepted administrative theories, and industrial research has profited from the experience. It seems certain that resource research could profit as well. This paper is based on an extensive literature review and on mail inquiries and personal interviews with more than fifty successful research administrators. Throughout the review, I found a uniformity of expression which demonstrates that basic principles of research administration are applicable to any form of research effort.

In general, four subjects were mentioned in the literature and by the people interviewed. These four, personnel, research atmosphere, organization, and the director of research, form a basic outline for presentation.

1. Possibly the first requisite of successful research is the selection and retention of good personnel. To some degree, well-trained, competent scientists can overcome other deficiencies of administration, but without such people, good research is impossible. Evaluation of competent personnel is not an easy task, but a number of factors appear to be important in determining research potential. Outstanding among these are the ability to recognize problems and the ability to produce potential solutions in quantity. Overall, a good man with research interest is needed; yet it is rarely possible to determine what qualities contribute to research ability as compared to those qualities which make a good administrator, or doctor, or lawyer.

Selection and retention of research personnel in resource work is further complicated by the fact that most resource work functions under some form of Civil Service. The associated low pay scales may serve as a detriment to resource research because competent people who might have entered resource research go into other, better-paying fields. Alternatively, Civil Service agencies can serve as schools in which inexperienced scientists train for better jobs elsewhere.

2. A second important facet of research administration can be broadly summarized as "research atmosphere." Most writers and research directors agree that the working environment is important to both quantity and quality of research results produced by a laboratory. The factors which combine to create a good research atmosphere, however, have only been partially identified. Those mentioned most often can be grouped in three general classes: a) those related to professional recognition, b) those related to professional freedoms, and c) those related to staff morale.

a. Professional recognition can be evidenced in a number of ways. Within an organization there should be a written, stated policy for research, and top management should express continuing, active support. Many industries have achieved this level of support by making the research director a member of the board of directors. Although this may require actual physical separation of research from production and management functions, the general consensus of industrial opinion is that separation constitutes the best arrangement.

Additional facets of professional recognition within the organization include salary scales equivalent to those outside research and a promotional policy largely dependent on scientific competence rather than administrative authority. Outside the organization, the most important factors appear to be presentation of papers and attendance at technical meetings. These not only raise individual professional stature but tend to enhance the company's technical reputation.

b. The second large group of factors influencing research climate are those relating to professional freedoms—the scientific and intellectual independence of the scientist. Many administrators recommend that problem selection be left to the scientists, as long as they stay within areas of general interest to the company; and all administrators agree that methods of attacking problems should be determined solely by the scientist—even when those methods appear to be circuitous. Scientific workers should also be free from day-to-day administrative rulings. A number of administrators, for example, mentioned that, since a creative mind does not work from eight to five, scientists should not necessarily be expected to keep specified hours.

c. A final group of factors in research atmosphere are those affecting worker morale. In varying degrees, this group includes such things as the residential environment; the quality and quantity of laboratory equipment and supplies; the potential for improving educational level within the organization through special leaves of absence or, in some cases, scholastic subsidies; and association with colleagues of high scientific stature.

3. The fact that freedom is a basic component of research atmosphere does not obviate the need for organization. Although industry has not been able to produce the perfect type of research organization, the errors which have been made in industrial research can help to provide positive guidelines for resource research administrators. In actuality, the only function of an organization is to hold operations together and make them work efficiently. In research, since efficiency can be at least partially measured by the number of ideas produced, the best organization is the one which allows the greatest number of thoughts to be expressed. Such an organization has at least two major attributes: first, it is flexible, so that the individuality of different scientists can be recognized; and second, it is as simple as possible, so ideas produced at the bottom levels will not be lost in transit through a bureaucratic ladder.

The observations mentioned most often in recommendations for designing a successful research organization were first, that the organization be built around available researchers, and second, that a double-ladder promotion system be established. The first recommendation is an extension of the basic concept of flexibility. It includes the observation that organization charts should be avoided because they create slots which available researchers may not fit. The double-promotional ladder consists of a series of professional advancement steps completely independent of any managerial series and available to scientists without administrative authority.

4. The final subject discussed in this paper is the director of research himself. The ideal research executive probably never has and never will exist. There are, however, a number of factors which seem to contribute to success in research administration. Among these are the ability to produce ideas and to provide inspirational leadership; the ability to administer research so that research goals are kept continually in mind; the ability to select creative people and to allow them to create; the ability to develop an atmosphere conducive to high-quality research; the ability to recognize creative people and to manipulate working conditions so as to

obtain the greatest possible scientific contributions from them; and the ability to explain and sell research objectives and results, particularly within the company. The director of research should be responsible for planning of future work and coordination of current work, and he should be capable of doing independent research of his own, even though administrative duties might preclude such activity.

Although the basic principles of research administration are fairly well defined by industrial experience, it is not possible to outline a specific model for resource research because no such model could be realistic. The functions of administration are to encourage creativity, maintain "research atmosphere", and evaluate results. Administrative patterns based on the precepts established by industrial research could produce substantial improvement in current resource research programs.

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APPENDICES

Appendix 1 — Quality in Personnel

ANDERSON AND STETTEN (1957): "First, acutely needed and absolutely essential is the mature scientist, and administration must do what it can to fill this need."

BARKLEY: ". . . in general, the best research is always performed by well-trained people with experience and strong motivating interest . . ."

BUZAN: "Demonstrated capability and performance have played a much greater role in the selection of our people than any other factors."

DALE (1960): "The major problem of the administrator in building a research staff is that of personnel selection."

DAVIS (1960): "One can have adequate finances and fine facilities and yet fail to achieve results for lack of able and well-trained personnel sincerely interested in research."

DRAKE: ". . . important factor is a staff having a high degree of competence in as many as possible of the fields with which our products might be concerned."

FARRELL: "No research at the Laboratory is conducted by anyone who is not a fully trained professional graduate in his field."

FROMAN: "We believe here that if an institution is limited by either budgets or space, it is well to weight the technical staff heavily with highly trained people, even if some Ph.D's have to wash some of their own bottles or wire up an electronic device occasionally."

GABRIEL (1943): ". . . quality is more important than quantity."

HOBSON (1960): "To deal successfully with greater technical complexity, you need people who match the problems."

KELLY (1957): ". . . the most important single factor is the quality of the professional people."

VAN CAMPEN: ". . . group leaders and project directors should be highly educated and experienced in the basic science of their departments."

WILLIAMS (1945): "The principal requirement for the successful central research laboratory are suitable personnel, good management, and a well-equipped plant."

YOUNG (1947): ". . . the first requirement for successful operation of research organized along project lines is to select a key man around whom each project will grow."

Appendix 2 — Research Atmosphere

ANDREWS: "The duties of the director include hiring of the staff and creating and maintaining an atmosphere conducive to research work."

BOYER (1950): "If a government agency or a business expects creative research, it must provide an environment and an atmosphere in which the research process can be carried on."

COOLEY: "Because of this evolution, and the fact that research centers began looking around for the proper environment . . ."

HILLIER (1958): "Having selected the creative individual, it is next necessary to provide a favorable environment for him."

LEONARD (1955): ". . . the most important single factor conditioning the quality of research is the atmosphere in which it is conducted."

PATTERSON (1945): ". . . , research and development in industry, as in the university, flourish best in an atmosphere of . . ."

Appendix 3 — Adequate Compensation

DALE (1961): ". . . , the administrator must be willing to struggle for salary schedules adequate to attract men capable of attaining the advanced degree."

SHEPARD (1945): "Remuneration of the research worker must be adequate or at least in line with the going wage for a particular job classification."

SIMON (1947): One of the theses of the German Forschungsfuhrung (group of four scientific leaders which governed all German research during World War II) was that salaries of research workers should be on a level with the highest in scientific work.

SMITH (1957): Referring to the East-West competition in science ". . . the great financial and prestige incentives for Russian scientists along with their massive material support, high scientific morale and excellence of training appears to pose a number of problems."

WILSON (1949): One of the obligations of management to research is to provide adequate compensation.

Appendix 4 — Educational Experience

BENGTSON: "Most of the members of the research staff are Ph.D.'s or the equivalent."

BUZAN: ". . . more than half of the heads of our technical departments do not have doctoral degrees; but all have made substantial contributions and have published extensively in their fields."

CAMPBELL: ". . . in the Technical Department half will be professional scientists or engineers. Advanced degrees are not as numerous as desired but will run roughly 60 at the Masters level and 30 with a Ph.D. or M.D."

CAPSALIS: "Approximately 60 per cent of the professional people hold advanced degrees and 20 have completed their doctoral studies."

COPENHAVER: ". . . a large percentage of our staff is made up of personnel with the Ph.D. degree."

FROMAN: "About a third of our professional staff are Ph.D.'s . . ."

HALLENBERG: "Of the 265 professional employees, two-thirds have their doctorates. Most of our recruitment for professional positions is at the doctorate level."

KELLY (1957a): ". . . industry should discontinue employing, for research and development, men with only four years of training."

LEA: "Ideally, I would think in any large group there would be one or more researchers of the Ph.D. level, or probably what is more important, good technically trained professional people who have creative abilities."

LEIGHTY: "Approximately half of my staff is composed of people with B.S. degrees or higher, and we have a sizable number of M.S. and Ph.D. people in the various research divisions."

MARSH: "Those in administrative and supervisory positions are nearly all college trained, some holding Doctor's and Master's degrees."

MCFEE: "Principal scientific investigators should be Ph.D.'s with several years of applicable experience, if possible—the more experienced the better."

POWERS: prefers to work with a mostly Ph.D. staff.

RUBLE: "Taking the branch head as an example, the minimum qualifications of the Civil Service Commission for these jobs are a Ph.D. or equivalent plus three years of appropriate experience."

TAPE: "Essentially all research activities are carried out by or under the direction of Ph.D. research scientists."

WEBB: "At Mellon Institute we employ preponderantly people trained to the doctoral level of science as our principal investigators. "This pattern is general in most research organizations, particularly those concerned with basic science . . ."

Appendix 5 — Papers and Professional Meetings

BELL TELEPHONE: "The Laboratories encourage participation in professional societies, so that the employee's contribution both to the scientific community and to Bell Laboratories is increased." "Employees at Bell Laboratories benefit professionally from the liberal publication policy."

CAMPBELL: "Participation in technical societies and publication in journals is encouraged within the limits prescribed by Congress."

DAVIS (1960): "Everyone needs to get around, know people and literature, and adequately present individual contribution in available written form."

FARRELL: ". . . they are encouraged to attend scientific meetings and to participate in similar professional activities that are a benefit, both to them and to the Laboratory."

FISK (1959): "Freedom of publication and encouragement of sound and timely publication, these, too, are important to the research environment and can be achieved in industry."

HILLIER (1958): "There must be an assurance of recognition for any valuable contributions the research man makes—by the individual's professional associates, both within the company and within the professional societies of which he is a member, and certainly by his superiors. A policy of early publication is one very important way of ensuring this."

MORRELL: "Within the organizational framework outlined, individuals are encouraged to exercise initiative and prepare scientific papers for issuance under their by-line."

SIMON (1947): in a summary of conditions to foster research: publication and distribution of reports should be limited only by broad policy relating to security, and membership in professional societies and attendance at meetings should be encouraged.

Appendix 6 — Autonomy of Personnel

BENGTSON: ". . . the degree of autonomy varies quite directly with the competence of individuals."

CAPSALIS: "Generally, the department heads and Project Engineers enjoy complete freedom in their operations after management decisions relative to technical objectives have been reached."

COPENHAVER: "All of our research people are encouraged to use up to 15% of their time to work on their own ideas rather than on formally assigned projects. We feel that this degree of freedom is essential for an organization charged with responsibilities such as we have."

CURTIS: "The autonomy of the individual staff members of the research staff in the Office, Chief of Research and Development is comparable with the research staff of most large industrial or educational institutions."

DAMBACH: "A great deal of autonomy of individual staff members exists on all research projects which we carry out."

DAVIS (1960): "the degree to which a researcher can be free to investigate anything that may happen to interest him is a highly debatable point. Almost always, some bounds have to be set."

DAVIS: "Research is an individual thing, and individuals do have to have a considerable degree of professional autonomy. This is one of the things that I think is often lacking in civil service work."

FROMAN: "Obtain able people, give them as much autonomy as possible . . ."

LEA: "To the extent possible, I believe that researchers work better and produce more given as much autonomy as possible."

LEWIS (1957): ". . . the people tested were generally more productive when they acted as individuals."

MULLEN: "Autonomous operation is encouraged at the level of laboratory heads. Individual initiative is a prime factor in the selection of the laboratory heads."

SMITH (1957): "The question can be raised: Since we have always believed that freedom is a necessary ingredient to the advancement of pure science how is it that Russian science prospers? The answer is likely to simply be that those Russian sciences which have advanced do have considerable freedom."

STOOKEY (1958): ". . . promising research men should be given . . . sufficient freedom, time, and independent responsibility to encourage their best efforts."

WILLIAMSON (1957): "The ability to inspire and the freedom to 'free-wheel' are probably intimately related."

Appendix 7 — Educational Encouragement

CAMPBELL: "Changing technology, recruitment problems and the like necessitate active programs both in-house and at Universities to upgrade and educate our personnel."

SIMON (1947): Summary of conditions which foster research, recommendations to the War Department. ". . . formal education, by subsidy or time off, should be encouraged."

U. S. FOREST SERVICE: "The Laboratory also encourages employees to pursue academic degrees at other institutions by granting leave of absence for this purpose."

Appendix 8 — Organization

BARKLEY: "You should use whatever type of organization structure and staffing pattern which seems most applicable to your particular problems, facilities and personalities of key personnel."

CAMPBELL: "The important function of the R & D organization is to enhance and make the best use of the capabilities and human characteristics of its staff."

DAVIS: "I don't think there is any fixed pattern about staffing; it all depends upon what you do, how you do it, and the kind of personnel one is working with."

GATES (1957): "The unanimous first class ranking for Great Britain in European research is a testimony to good organization. In fact, the organization of science in Great Britain is so thorough to the form of councils, committees and societies one wonders where the scientist himself gets time for research."

LEA: "We try to keep our organizational lines as loose as possible as far as actual experimentation is concerned since many of our projects involve the personnel of several different groups."

MCFEE: "Concerning staffing the research organization, an important point to be kept in mind is that the type of staffing pattern must be appropriate for the level and scope of research carried out in the organization."

SUITS (1956): "The fact that we do not have a common pattern for the organization of the laboratory work of the operating components is an indication that this subject is still evolving and developing in our company."

WEIDLEIN AND HAMOR (1936): "We regard a research organization as a body of scientists who are combined through system and regulation into a coordinated whole."

Appendix 9 — Organization Charts

AUSTIN: "When you get down to smaller groups within each laboratory, I believe you must maintain considerable flexibility of organization and, in fact, in many cases this organization must be built around the men you have available rather than designed to fit some abstract organization chart."

MEES (1945, in Discussion after Midgley): "You don't have to plan or organize the research itself, but you must have an organization among the men. This is usually expressed in a chart and, frankly, I don't think that those charts mean anything, . . ."

Appendix 10 — Double Ladder for Promotion

DAVIS: ". . . the U. S. Forest Service is putting considerable emphasis on giving research itself more real recognition. It works out by changing promotion and classification requirements so that an able researcher with no particular administrative organization—people who he is responsible for, etc.—can get up into top grades."

SIMON (1947): in a list of recommendations on the conditions which foster research mentions that U. S. Civil Service laws should be revised so that supervisory capacity is not required.

TERRILL: ". . . it is well to have a category such as 'Senior Scientist' for non-administrative personnel—to permit salary and other benefits of at least equal character to those given administrative personnel."

Appendix 11 — Duties of the Director of Research
(Where cited to a company, these lists are condensed from job specifications and position guides.)

AUSTIN: "His major responsibility should include choice of the main areas of work, or, at the least, recommendations as to what these should be. He should also be concerned with picking the key people for the staff. Usually, he is responsible for preparing the budget for his group and for administering its control. Likewise, he should study what new facilities may be needed and then see what can be done to obtain them. He must administer the policies for detailed operation of his group."

BARTLETT:

1. Liaison with Denver (central clearing for research problems).
2. Handles public relations, salesmen, conferences, etc.
3. Financial aspects of operation.

CAMPBELL: ". . . the Technical Director is . . . concerned with scheduling and seeing that a reasonable report is issued."

COPENHAVER: ". . . I am charged with the responsibility for implementing research leading to new and unrelated products and to provide the company with a sound technical foundation for continued growth. I am charged with the direct supervision of the Central Research organization, selection of, training, development and promotion of qualified personnel and their compensation within established company policy. I prepare and submit annual budget requests."

CUTTER LABORATORIES:

1. To provide leadership and direction, coordination with over-all research program.
2. Create ideas and stimulate creation of ideas.
3. Provide definition of objectives.
4. Select and train personnel.
5. Provide space, equipment and supplies.
6. Furnish technical guidance.
7. Inspire, develop and maintain an atmosphere of enthusiasm and pride.
8. Provide reports on progress.
9. Coordinate with other divisions.
10. Provide contacts with members of other research departments, universities, clinics.
11. Adjust the assignment of manpower and equipment according to priorities established by the Vice President for Research.
12. Evaluate the progress of projects.
13. Provide stimulating professional contacts for the men.
14. Maintain a suitable knowledge of the science.
15. Get new information to the proper parties.
16. Consult with other divisions.

DAVIS: "What he can do is understand research and create a general climate and understanding of it under which it prospers."

GENERAL ELECTRIC COMPANY RESEARCH LABORATORIES:

1. Build company leadership in all aspects of scientific research.
2. Communicate and teach resultant opportunities to company components.
3. Formulate and recommend company policy relative to this function.
4. Maintain a clearing house for research operating information.
5. Aid operating components on request.
6. Aid the executives in planning, particularly for this function.
7. Participate in national and international scientific affairs as appropriate.

HILLIER (1958):

1. To participate in the selection of creative individuals.
2. To manage his team to provide maximum freedom of action within existing boundary conditions.
3. To participate in the formulation, interpretation, and acceptance of realistic research objectives.
4. To maintain appropriate and realistic pressure toward accomplishment.
5. To assure appropriate recognition of contributions made by the individual members of his team.
6. To maintain communication between his group and the other parts of the laboratory and the company to provide knowledge of stimulating activities and to provide association of stimulating individuals.
7. To play an appropriate role in the provision of adequate facilities and technical assistance.
8. To understand and stabilize the personnel problems involving creative individuals.

ORTH (1959): . . . the manager should . . .

1. . . . refuse to impose rules and regulations on the professional staff which imply their lack of intelligence, maturity or understanding.
2. . . . insist on consulting with professional workers about plans or proposals which will affect them and/or their work before decisions are made.
3. Within reasonable limits imposed by the business situation, . . . allow researchers considerable freedom to plan their own work.
4. . . . encourage (but not press) scientific personnel to keep up with their fields and to add to their professional stature by attending meetings of professional societies and writing and delivering technical papers."

OWENS-ILLINOIS TECHNICAL CENTER:

1. Develop and maintain adequate research organization.
2. Interpret corporate objectives in terms of research and observe that research is related to broad objectives.
3. Direct or recommend new areas of research.
4. Direct or recommend abandonment of areas of research.
5. Assure transfer of fundamental information to development.
6. Encourage consultation of research personnel with outside contacts, among selves, etc.
7. Stay abreast of technology in the field.
8. Develop outside research activities (universities, etc.).
9. Maintain adequate follow-up on patentable ideas.
10. Provide specialized service to technical directors.
11. "Administer corporate policies with respect to scientists in the way most probable to motivate and inspire effective and creative research activities."
12. Serve on Company Technical Committee, etc. as requested.

13. Enhance the Company's technical reputation (publications, etc.).

POWERS:

1. Coordinate research effort.
2. Advise (if technically qualified)—this advice need not necessarily be followed.
3. Handle finances, visitors, etc.

U. S. ARMY (1961) DIRECTOR OF ARMY RESEARCH:

1. Plans and directs the research program of the Army.
    a. Provides maximum utilization of available scientific talent.
    b. Provides dynamic program responsive to future requirements.
    c. Fosters the best possible atmosphere for prosecution of research.
    d. Provides liaison with civilian scientific community.
    e. Encourages scientific training and education.
    f. Furthers civilian activity in areas of interest to the Army.
2. Establishes policy, plans and program guidance.
    a. Develops and justifies budget.
    b. Reviews and coordinates research activities with other departments.
3. Monitors research projects undertaken by the Army.
4. Furnishes advice and recommendations concerning biological and medical programs.
5. Supervises activities of various research offices.

WEIDLEIN AND HAMOR (1931): "The chief requisite in a laboratory-director or research-department head is ability to recognize and utilize effectively the personal qualities of men that lead to their success in scientific investigation."

WILLIAMSON (1955):

1. Plan for the future.
2. Make and adhere to policy decisions.
3. Organization: place each worker for effectiveness.
4. Get jobs done and carry out policies.
5. Delegate routine work and repetitive details to free scientific personnel.
6. Evaluate and stimulate investigation.
7. Insure economic evaluation and production practicability.
8. Integrate division with rest of company.
9. Have legal knowledge.
10. Have salesmanship.
11. Have diplomacy.
12. Schedule work—be sure it's done and stop it at the proper time.

Appendix 12 — Supervision of Research

AUSTIN: "As to the degree to which he should actually direct research I believe this should be kept to a minimum."

BUZAN: ". . . he does not concern himself so much with 'directing' the research already under way as with seeing that the Laboratories is active in the right fields and has a proper balance of basic and applied research."

DAVIS: "Neither do I think he can actually and literally direct a good deal of research. What he can do is understand research and create a general climate and understanding of it under which it prospers."

FROMAN: "In my opinion, the best research 'direction' is no direction at all by the research director unless he happens to be an authority on the specific item under consideration."

HALLENBERG: ". . . but does not direct the research in the sense of guiding or appraising the individual scientist's work. This phase of the Laboratories' activities is in the hands of the first level of supervision or, in the case of the Senior Scientists, it is in their own hands."

HOLLAND (1947) Madam Joliet Curie: ". . . you *cannot direct* research—research must *direct you*! If my mother had been directed in her researches, she would have found small things. She never would have discovered Radium."

JONES (1947): "The executive who tried to supervise a competent research scientist in the usual organization sense of supervision is more likely to do harm than good."

KAHAN: "We try to operate with the philosophy that our job is to facilitate rather than direct research."

LEA: "I personally like to have my associates operate with as much autonomy as possible and prefer that the Director does not become involved any more than is necessary except where departmental or company policy is involved."

LEONARD (1955): "In the long run, needlessly detailed supervision may cause potentially able researchers to degenerate into mere technicians, while inadequate direction is almost sure to result in incoherencies and inconclusive, never-ending 'programs', and to encourage dilettantism."

TERRILL: ". . . I don't believe that he can 'direct' each phase or project in his laboratory without bogging down the whole program. If he tries to do so, he will certainly diminish the possibility of creative ideas which generally stem from people actively at work in a given area."

VAN CAMPEN: ". . . , I do not believe that a research director should ever direct the actual conduct of a research project, since those closer to it in the laboratory are much more capable of evaluating results and planning the subsequent approaches."

WEBB: "Directed research is more applicable to problems which can be completely defined."

Appendix 13 — Research by Director of Research

BENGTSON: ". . . the Vice President and Director of Research . . . does not personally engage in research work."

BUZAN: ". . . Dr. Hafstad, our Vice-President in charge of Research, simply has too many demands on his time to conduct research on his own."

CAMPBELL: "The size of the organization and complexity of work preclude the conduct of any research on his part."

COPENHAVER: "I do no research of my own, . . ."

DAVIS: "I don't think a director of research can actually conduct much research of his own or should hope to, although it is a nice idea and one always *wants* to, or should."

FARRELL: "In the strictest sense, he does not actively conduct his own research."

FROMAN: "Most regrettably, I personally find little time for research."

MARSHAL: "Because our department is quite large the upper administrative levels seldom get time to do any active research themselves."

MURRAY: "The Section Head, in general, conducts some research himself, whereas, the Division Head likely does none."

TERRILL: It depends on the number of people involved. ". . . an organization could be set up somewhat along the lines of a University Graduate School, where the Dean frequently carries on research in his area of specialization."

VAN CAMPEN: ". . . , I believe the usual research director always will have too much administrative work to do to conduct any research himself, although I realize there are some exceptions who will attempt to do this."