a FUTURE for PHYSICISTS in INDUSTRY

By **C. G. Suits**

ONE of the things that characterizes the trend of industrial research since World War II is the increasing demand for physicists in a great variety of industrial laboratories. Unlike the chemist, whose important role in industrial technology has long been recognized, the physicist is a relatively new figure on the industrial scene. Thus, it is timely on the occasion of the twenty-fifth anniversary of the American Institute of Physics to examine the present status of the industrial physicist and to assess his opportunities for the future.

The Industrial Market for Physicists

WHEN the AIP was organized, twenty-five years ago, the term *physicist* had a mysterious and slightly unpleasant sound outside academic circles. The occasional misguided physicist who had found his way —by accident or design—into industrial research was an unsung and rather lonely adventurer.

But the activities of these early explorers in the industrial jungle soon began to pay dividends, a fact that stimulated industry's interest in physics and resulted in more recruits. Over the past quarter century the steady contributions of these pioneers and their successors have earned for the physicist a secure and valued position in industrial research. It is common knowledge that the mobilization of physicists during the war was an important factor in the success of our war effort. This mobilization influenced the future of the American physicist in two ways: It introduced him to the opportunities afforded by a scientific career in industry, and it brought forcibly to the attention of industry *its* need for the skills and talents of a hitherto almost untapped profession.

The post-war industrial expansion has brought about a critical shortage of trained scientific manpower. This limiting factor to civilian and military technology has become so important that the Scientific Manpower Commission conducted a comprehensive survey of the problem, the findings of which were published in a series of reports.[1] In Scientific Manpower Bulletin No. 6, August 1, 1955, there appears the following statement: "The survey findings clearly indicate that, on a nationwide basis, the supply of qualified personnel is insufficient to meet the demand for research and development scientists and engineers in many fields." Half of the 200 companies surveyed indicated that they were unable to hire enough research scientists and engineers to meet their needs; and many who were not suffering from *numerical* shortages emphasized their need for *better qualified* technical personnel.

Moreover, all indications point to the fact that these shortages are due to become still more acute. Dr. L. A. DuBridge, speaking to the Fourth Conference on Scientific Manpower at Berkeley in December 1954, summarized the outlook as follows: "There is, in short, a gilt-edged, money-backed demand for more scientists, not only just a need." Dr. Howard Meyerhoff, Director of the Scientific Manpower Commission, says: "For physicists, no definitive employment study is available, but in 1954 there were 3150 graduates at all degree levels and all were absorbed by industry, education, and government. The prospective number of graduates in 1955 is smaller, but the demand has remained steady."

There are no reliable figures on the specific require-

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[1] Scientific Manpower Series, 1951.

ments for physicists in industry, but one thing is certain—the supply will fall far short of the demand. As a consequence of this situation, the physicist upon completing his doctorate now finds himself in a position only slightly less enviable than that of a lone G.I. marooned on a desert island with a platoon of Wacs. In fact, the tantalizing opportunities confronting the young Ph.D. in physics today are so many and varied that it is not easy for him to make the right choice. Like the G.I., he is in danger of being swayed by superficial considerations.

Without underestimating the value of financial emoluments, I would remind the young scientist who is flirting with several attractive alliances that there are other forms of remuneration that are essential to a useful and satisfying career. Among these equally important—but often less obvious—attractions are: the opportunity to pursue a line of work most suited to his interests and aptitudes; the privilege of constant association with fellow scientists—associations that will continually enrich his professional life; freedom to publish his research findings and to participate freely in the activities of professional societies; adequate physical facilities for research; and, most important, support by a management that has an understanding of the nature of scientific research and the attitudes and motives of the research scientist. These are the professional factors that determine whether the proposed alliance will be a congenial one, and will lead to long-term satisfaction. They should receive at least as much attention as the personal and family considerations that always enter into such a decision. Research positions in industry vary widely in the extent to which they combine these factors.

The Climate of Industrial Research

OCCASIONALLY a young scientist nurtured in the refined environment of the university will express misgivings about the climate of industrial research. He is sometimes troubled by the fear that the atmosphere of the industrial laboratory may be polluted by "fall-out" from the market place. It is undeniably true that the objective of most industrially sponsored research is to contribute to the advancement of modern technology. In this sense, industrial research is more definitely programmed, and the industrial scientist is perhaps more alert to possible eventual applications of his results than is his brother scientist in the university.

It does not follow that all industrial research is of the kind known as *applied* research in which the aim is to find a solution for an immediate technological problem. On the contrary, the progress of technology in a particular field involves a number of related steps, one of which is the fundamental search for new knowledge, unbiased and unhampered by commercial expediency. Basic research is recognized by the progressive technical industries as the broad foundation upon which all other steps in technological progress must be built. Enlightened management no longer regards the research scientist as a novelty and his professional employment an industrial luxury.

Far from limiting the creativeness of a research scientist or detracting from the professional satisfaction that he derives from his work, the impelling factors in industrial research more often than not work to the scientist's advantage. For one thing, the hope of eventual pay-off assures the provision of adequate funds and facilities to pursue a given scientific venture. In industry generally, every practical means is provided for lengthening the arm of the research scientist.

The attainment of business objectives depends upon the effective utilization of professional skills. In research this means providing a stimulating working environment with respect to the specialized facilities and the supporting skills that are essential to scientific productivity. It further means the creation of a professional climate that is conducive to creative work. Only by a progressive attitude and a realistic plan with regard to these matters can an industrial organization hope to acquire and retain top grade scientists.

One great source of satisfaction in industrial research comes from seeing useful results carried through to fruition in the form of tangible contributions to our technology. It is my observation that even the most dyed-in-the-wool "pure" scientist is gratified when a useful application for his results is found. I know of no present-day scientist who maintains the attitude of a mathematics professor I once knew who bemoaned the fact that physicists had at last found a practical use for matrix algebra. The bogey of creative genius stifled by the turbid atmosphere of the market place is as unreal as Banquo's ghost. Although a few areas of industrial research may be somewhat clouded by the smog of economic necessity, in the main, the atmosphere is wholesome and invigorating.

The *local* climate of industrial research is influenced by a number of factors, one of which is the size and character of the research program. In a few of the larger industrial laboratories, the scientific community does not differ greatly from its academic counterpart; but the difference is more marked in the case of the smaller laboratories scattered throughout industry, many of which are found in the specialized components of large industrial organizations. There the mutual stimulation and intellectual cross-fertilization afforded by a large and diversified research staff is somewhat limited. A possible compensating factor in smaller laboratories may be the greater incentive—and perhaps greater opportunity—to develop self-reliance and individual initiative.

In the case of the small laboratory, and more particularly, in situations involving a single scientific specialist in an advanced engineering component, the creation of a satisfactory research environment entails some special problems. The solution of these problems frequently involves utilizing the community of interests represented by the professional personnel and the scientific activities of universities and colleges in the vicinity. Both formal and informal associations between

adjacent industrial and educational institutions may be enhanced by taking advantage of individual consulting services available from academic laboratories and research institutes in the community.

One very effective means of supplementing the professional life of the research scientist in industry is afforded by extended leaves for research and study in universities; this may, in fact, be regarded as a sort of industrial research "sabbatical". For the scientist who is somewhat isolated in a special component or in a small laboratory, such an experience provides a needed stimulation and serves to keep him up to date on progress in his field. Another practice that strengthens the industrial scientific community—especially in the case of small laboratories—is the employment of university scientists during their vacation periods. These exchanges usually result in mutual benefit both to the university and the industrial laboratory.

Generally speaking, research organizations associated with diversified business interests and hence concerned with diversified technology are less committed to immediate problems arising from product interests than are the smaller, more specialized laboratories. Moreover they can afford to extend their research programs over a wider front—a situation that may provide greater freedom in the choice of field of endeavor for the individual scientist. On the other hand, some highly specialized businesses have found it profitable to carry out basic research on a broad front. The character and diversity of the research program is, of course, determined by the technological nature of the industry. In industry generally, diversification is regarded as a desirable business objective, and, in a progressive industry, a broad-gauge research program is a positive step toward diversification. Differences in character will be found among industrial laboratories just as among academic institutions. Individual inclinations differ, too, and a professional alliance is the happiest when the scientist selects a climate most conducive to his professional health.

At this point, it may be worthwhile to compare the philosophies of the management of academic research and industrial research. Traditionally the academic research program was determined very largely by the interests of the members of the permanent staff and by the physical facilities of the laboratory. The prime motivating factor was curiosity, and the filling of a technological need was a secondary consideration—often, purely incidental.

This situation has altered significantly over the past decade. The large research programs in our leading universities—particularly programs supported by government contracts—frequently are aimed at definite practical objectives. In other research programs—such as nuclear research—where the objectives are purely scientific, the exceptionally heavy investment in highly specialized facilities may have as a corrollary the detailed programming of many phases of the research work. In many cases of this kind, the requirement of extensive teamwork coupled with rigid programming inevitably places a limit on the freedom of choice of the individual members of the team.

In the industrial laboratory, business objectives are a determining factor in the motivation of management, and the programming is based upon known problems or classes of problems for which solutions are needed and upon which available scientific background and research techniques can be brought to bear. Areas of investigation—both basic and applied—are selected on the basis of their potential contributions to a given technology. Forward-looking management, however, has come to appreciate the important role of broadly supporting basic research as well as the immediately practical aspects of applied research; it has, therefore, found it expedient and profitable to support an integrated program involving all of the steps in the technological process. A case in point is applied research directed toward the development of new high-strength, temperature-resistant alloys. This applied research rests upon basic studies of phenomena related to the strength of materials. Fundamental knowledge of the phenomena of fracture, crystal defects and dislocations, and nucleation—factors that enter into the strength of materials—is essential for a progressive approach to the design of high-strength materials. The great diversity of problems encountered in the various aspects of industrial research affords a wonderful opportunity for the industrial research worker to learn new techniques that constantly broaden his background.

Versatility and flexibility are invaluable characteristics in a research physicist in industry, and the transfer of training from one field of research to another is a common experience in industry. As an example, in the past decade, there have been many more graduate students specializing in nuclear physics than in solid-state physics. However, the opportunities afforded by solid-state studies have been so great that many nuclear physicists have shifted to solid-state research, a transfer that at once provides a challenge to the nuclear physicist and enriches the solid-state field. Similar transfers frequently occur in other areas. An interesting example of the broadening effect of such transfer of interest is the case of a team of physicists in our laboratory who during the war specialized in underwater sound-signalling, subsequently became authorities on methods of measuring flame temperatures, then specialized in thermal conductivity studies that resulted in a completely new type of thermal insulation, and finally became experts in the highly specialized field of superpressure-supertemperature research.

Of course, in some of the larger research organizations there are some complex fields that can only be explored by highly specialized scientists, many of whom devote their entire careers to their specialties. What I have said above is not intended to minimize in the least the important role of the confirmed specialist, but merely to emphasize the multiple opportunities confronting the physicist in industry. This infinite variety of challenging problems is a characteristic feature of the climate of industrial research.

Areas of Opportunity

ANYTHING like a comprehensive survey of the various fields that offer challenge to the industrial physicist is beyond the scope of this paper. I shall mention only a few. In doing so, I wish to emphasize the fact that no one can predict the future of science with any confidence in the accuracy of detail; but the following are some of the broad areas of opportunity open to the physicist.

One of the broad areas of interest that invites extensive fundamental research and that is also proving to be very fruitful in technological applications is solid-state physics. There are two aspects to the study of solid-state phenomena. One important area of investigation has to do with properties of matter that are governed by *atomic* behavior. In this area, we are concerned with the structure and the mechanical properties of crystals and with the transport of atoms by diffusion. The strength of materials, the causes and mechanism of fracture, and the phenomena of plastic and elastic deformation are very important aspects of the atomic behavior of matter in the solid state. An equally important area has to do with those physical properties of matter that are related to *electronic* behavior. The phenomena of magnetism, semiconduction, light emission, and dielectric properties lie in this area. These fields are literally teeming with pressing problems that invite both basic and applied research on a broad front.

Another broad area of opportunity—one of especial interest to the nuclear physicist—is reactor physics. The recent modifications of the Atomic Energy Act have made financial investment in the development of atomic power sources more attractive to American industry. This new situation multiplies the opportunities for physicists interested in problems related to the design and operation of reactors. Reactor physics is a good example of a field in which basic and applied research constantly overlap and supplement each other.

An important field just appearing on the scientific horizon is the industrial development of thermonuclear processes as a source of power. As this field develops, there will be numerous opportunities for research physicists in many fields of specialization.

A new field of activity that will doubtless provide many opportunities for the physicist of tomorrow is missile research, including those aspects represented by hyperdynamics, combustion, properties of high-temperature materials, and instrumentation. In addition to the great variety of obvious engineering problems, there are innumerable intriguing scientific problems associated with this new field of endeavor that will afford opportunities for physicists over a wide range of specialization.

An area of steadily increasing importance is that of communication and information systems. The field of information theory is in its infancy. The elucidation of the science of information and the development of techniques for processing information are wide-open fields in the development of which the physicist must play a fundamental role.

Another field is that of physical electronics, which is concerned with the physics of the elements that ultimately enter into the make-up of devices and systems.

The increasing demand for the disciplines and techniques of physics in other areas of industrial research is a concomitant of our expanding technology. As an excellent example of this, consider what has happened in metallurgy. Twenty-five years ago, metallurgy was primarily an industrial art, and metallurgical research consisted chiefly of the empirical application of standard techniques. During the past quarter century, however, a renaissance has taken place in metallurgy, and now physicists and chemists are finding a challenging outlet for their talents in fundamental studies of the solid state of matter represented by metals and ceramics. For example, in our laboratory 20 percent of the professional staff of the metallurgy department are physicists. Today physicists are in demand in practically every area of the physical sciences.

I have referred above to the case of the individual scientist who is working in a more or less isolated situation with limited provisions for supporting skills and services. This is a situation that demands a qualified "general practitioner" in science rather than a scientist highly trained in a single field of specialization. The general practitioner in science is expected to serve as scientific consultant on a great variety of problems. For this kind of position, a diversity of interests and a broad-gauge training are essential. This type of assignment is a difficult, but challenging, one. By the very nature of the job, the scientist in such an assignment is deprived of daily contact with fellow scientists, and yet he is confronted with the necessity of keeping up to date in a number of fields. There is very great opportunity in industry for the versatile physicist who is willing and able to fill this kind of assignment.

In conclusion, I should like to acknowledge industry's debt to the universities. Industrial research depends upon the educational institutions for its most important commodity, technically trained personnel. While industry is vitally concerned with the immediate problem of staffing its existing and planned research programs, it is also concerned about the long haul—the continuing supply of trained scientists, which can only be assured if an adequate number of qualified scientists choose a career in teaching at both the high school and the university levels.

The development of a stable and realistic system for the support of our institutions of higher education is one of the important problems of present-day American society. Industry is showing an increasing awareness of the problem and of its responsibility for a proper share in the support of the educational institutions upon which the progress of American technology depends. Forward-looking industrial management is searching for effective ways of contributing to the solution of this vital problem, and encouraging progress is already in evidence.