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THE PROFESSIONAL ENGINEER

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PREFACE

THIS monograph is one of a proposed series dealing with the present status of certain established or emerging professions in the United States. The studies were originally planned for publication as chapters of a single volume comparing conditions in the professions. This plan was abandoned, however, since it seemed probable that they would serve a wider purpose if issued separately. Social Work as a Profession, the first of the series to be published, appeared in May, 1935; a revised edition in May, 1936.

Although there is a large body of literature on the professions, it is often so scattered and sometimes so difficult to obtain that much of it is not used by professional people themselves and even less of it is known to the laity. In these monographs, therefore, significant data obtained from interviews, questionnaires, books, periodicals, and unpublished studies have been assembled and interpreted in such fashion, it is hoped, that the information may be readily utilized by vocational counselors and those who are striving to make the professions contribute more widely to the welfare both of their members and of society.

Because it is possible, within the compass of a small volume to present only a fraction of the material relating to the given subject, those facts have been chosen that seem to explain the reasons why a particular group has reached its present degree of effectiveness. No one would dispute the assumption, for example, that today adequate preparation constitutes one of the most important elements of successful practice. So vital is formal training that a large proportion of each monograph has been devoted to a discussion of its evolution and the problems incident to it. Similarly, since professional associations are capable of doing much to raise standards of practice and of determining what the relation of a group to the society it serves shall be, the most important of the national associations are described at some length.

It is generally recognized that one of the most serious problems of the professions is the lack of an accurate determination of the number of persons who are needed in a specific group, and the lack of a form of control that would regulate the numbers to be admitted in the interests of the public and of the group. A corollary to this problem is the uneven distribution of professional service in the various sections of the United States, and the widespread lack of agencies for counseling new members of these professions about selecting localities in which to settle.

There is also the equally important problem of the inability of large numbers of persons receiving low incomes, especially in rural areas, to purchase as much professional service as they need. Even when service is paid for by the government or private philanthropy rather than by the individual, its quantity and quality vary in a marked fashion from one locality to another. In the face of these difficulties, there have been set down such data as could be obtained on the number of persons engaged in a particular profession, their distribution and earnings, and the demand for their service as compared with the need for it. Experiments in new ways of providing service have been noted, in so far as these experiments may result in more satisfactory working conditions for the members of the groups described and in extended service for the public.

Each study ends with a survey of recent trends within the profession under consideration. These trends indicate the ability of the group to adjust itself to the ever changing conditions in our social life.

THE PROFESSIONAL ENGINEER

ENGINEERING is primarily the art of applying the resources of materials and power in nature to the use and convenience of man. Engineers translate the discoveries of scientists into structures, machines, and processes. Aside from this aspect of their work, which is generally recognized, there is another that must not be overlooked: their function is becoming increasingly more extensive than the application of science to physical creation. They are being called, to a constantly greater extent, to occupy positions of a managerial nature, not only in their particular field of engineering, but in industry, business, public health, banking, and the administration of public affairs.

There are five principal divisions of the profession, although actually there is no clear-cut method whereby they can be separated into distinct categories. They are:

Civil Engineering, which includes the design and erection of structures of steel, masonry, and wood; the building of railways, highways, and inland waterways; the supplying of water and the disposal of sewage; the construction of harbors, docks, airports, subways, dams, and a multitude of other works.

Mechanical Engineering, which deals with the production of power from fuel and water, with the design and manufacture of machines, and with the direction and operation of the power and manufacturing industries.

Electrical Engineering, which is concerned with the application of electricity to power, light, communications and transportation, and the manufacture of appliances used for these purposes.

Chemical Engineering, which relates to the design, construction, and operation of works for the production of chemicals, foodstuffs, materials of construction, and other products in which chemical processes are a factor.

Mining and Metallurgical Engineering, which consists of the extraction of ores and fuels from the earth, and with their refinement and adaptation to commercial use.

Each of these five branches may be further divided into numerous specialties. Thus the technical subdivisions of civil engineering, for example, include structural, sanitary, highway, railway, municipal, and hydraulic engineering, and surveying. The work of engineers is likewise diverse. They may be employed as designers, constructors, or research workers, and hence be concerned chiefly with the technical aspects of the profession; or they may deal primarily with the direction and supervision of industrial enterprises.

Engineering in its broad scope is a profession that employs persons with varying degrees of ability and training. It has within its ranks men whose training ranges from the most advanced scientific and technological education to very little formal education. Engineering enterprises require the services of three groups of men: professional engineers, whose primary functions are planning and directing; technicians, skilled in developing details of plans; and engineering artisans, whose manual dexterity and experience are needed to carry out plans. Of those who operate engines and other machines many are called engineers, but their occupations are not recognized as engineering in the professional sense. All three of these groups are essential, for without them engineering plans could not be executed. As a matter of fact they merge into one another to such a degree that it is sometimes difficult to differentiate between the technician and the professional engineer. Many men, moreover, are constantly in the process of raising themselves from a lower to a higher category.[1]

Trade schools and technical high schools are designed to provide training for engineering artisans. Many learn their vocation, however, by being employed on the job or by the apprenticeship method. There are a few technical institutes that prepare a relatively small number of technicians. These will be described in a later section. The ranks of this group are supplemented by men who work up from the artisan level and by some graduates of engineering colleges who begin their practice as technicians. The schools of engineering that confer degrees are especially designed for the formal training of professional engineers who wish to enter the fields of planning and management. The instruction that they give is supplemented, after completion of the academic course, by supervised practical experience in industry.

The following pages are almost entirely concerned with questions incident to professional engineers and the practice in which they engage. Hence the terms "engineer"

[1] Engineering: A Career, A Culture, published by the Engineering Foundation, New York, 1932, pp. 5–8; The Engineer and the Chemist: Their Careers and Their Education, published by the Polytechnic Institute of Brooklyn, n. d., pp. 4–12.

and "engineering," unless otherwise designated, will refer to persons and engineering work on the professional level. Since graduation from an engineering college is now considered the most desirable first step in the process of becoming a professional engineer, much of the subsequent discussion will deal with the evolution of these colleges and the nature of the training they offer.

ENGINEERING EDUCATION

Evolution of Engineering Colleges

Before the beginning of the nineteenth century, the engineer obtained his preparation as an apprentice to an older engineer or through employment in a factory or shop. In 1812 when the United States Military Academy was opened at West Point as a training school for army officers, certain courses in the sciences and in the application of engineering were introduced. They represent the first formal instruction for prospective engineers in this country. In 1823 Stephen van Rensselaer of Albany arranged for the establishment of a school at Troy, which later developed into a polytechnic institute planned to deal "with all matters cognate to architecture and engineering." Thereafter, until the middle of the century, when the Lawrence Scientific School was created at Harvard and the Sheffield Scientific School at Yale, the West Point Military Academy and the Rensselaer Polytechnic Institute divided the honors of supplying the country with professionally trained engineers. Between 1850 and 1862 engineering courses were begun in at least five other schools. In the latter year the Morrill

Act was passed which granted to the several states federal aid for the founding of colleges of agriculture and the mechanic arts. This served as a great impetus to the establishing of more engineering colleges. By 1870 there were 17, in 1871 there were 41, in 1872, 70, and in 1880, 85.

Although the Morrill Act provided funds for schools and thereby made them possible, certain economic developments of the nineteenth century were important factors in stimulating interest in engineering education. The period from 1820 to 1870 witnessed the decline of certain occupations and the rapid growth of others. Agriculture had begun to lose its position of pre-eminence, and the percentage of the working population engaged in it decreased in fifty years from 83 to 48. During the same period the percentage in manufacturing, trade, and transportation increased from 17 to 31. Even more important was the advent of the railroad, which resulted in making the training of civil and mechanical engineers for railroad construction a major objective in a number of schools.

The engineers of the early decades of the nineteenth century were a scattered group of land surveyors, builders of roads, canals, and bridges, and practical constructors of machinery, who had been largely self-taught. As science developed and machinery became more and more complex, the need for specific preparation grew to be urgent. During the last fifteen years of that century, industrial expansion and progress in invention were so great that they caught the imagination of the people. Engineering education "came into its own." It grew in popularity both in institutions of higher learning and in independent technical institutes until it threatened not merely the supremacy, but even the actual existence, of classical courses. The 85 colleges of 1880 with engineering curricula had become 110 by 1896. This rapid progress was temporarily checked early in the twentieth century as agricultural education assumed more prominence and academic training for business came to be emphasized. The events of the World War, however, served to direct attention again to engineering education. The prominent place gained by engineers in the direction of industry, their notable contributions to the technique of production, and the conspicuous position which they occupied in war work were a fresh impetus for the founding of still more technical colleges. As a result, there are now about 160 engineering schools which confer degrees.

In looking back over the stretch of more than a century since formal training for engineering was first instituted in this country, one notes that the year 1870 seems to divide the evolutionary process into two distinct parts. The earlier or formative period was marked by the creation of the first few schools and their programs; the dominating personalities of these institutions were more often scientists and publicists than engineers; and their chief aim was the preparation of civil engineers to meet the problems of an era of rapid geographic expansion and of growth in urban population. After 1870 came a period of enlargement and ramification based on the models already created. Engineers of distinction took an increasing interest in education; an American literature of engineering began to develop through the authorship of leading professors and technical men; the profession took on solidarity and began to influence the scheme of education; and an extraordinary expansion of industry created a wide field for mining, metallurgical, and mechanical engineers.

There was also a marked change of educational method after 1870. In the earlier years there had been little use of the laboratory as a means of instruction. Much emphasis had been placed upon practical exercises in the drafting room and the field, and these, together with occasional demonstrations by science instructors, had sufficed to round out the formal teaching of the classroom. The most noteworthy features after 1870 were the great growth of laboratories and the laboratory method of scientific investigation and experimentation, and the gradual relinquishing of attempts to make engineering instruction as practical as possible. Nevertheless the acceptance of this academic type of education by the profession and the industries was not won without a long struggle. Traditions, carried over from pioneer days and reinforced by British example and influence, kept alive the distrust of theory and emphasized its detachment from practice. With the opening of the field of electrical engineering in the eighties, however, followed by that of chemical engineering in the nineties, there was a distinct turning away from the attitude that training should be intensely utilitarian. The new tendency was to make it more scientific and liberal. Industry gradually assumed responsibility for the practical training of the student. Thus the college was finally left free to devote itself to the scientific foundations that have proved themselves so essential to the further advancement of engineering.

Technical education has reflected in its evolution many of the virtues and the weaknesses of American education in general. It had its birth in a popular movement to promote "the application of science to the common purposes of life." There was at first little thought of creating any formal discipline for the profession of engineering; the aim was rather to give mechanics such an education as would enable them to become skilful in their vocations. Although a professional attitude soon appeared, training developed sporadically and without any underlying pattern. Significantly, however, this training was initiated by teachers and nearly all schools were on an academic basis from the beginning. Thus it escaped the pitfalls of early vocational preparation in the legal, medical, dental, and other professions, which grew either directly out of apprenticeship or out of proprietary schools conducted by practitioners.

Like other types of education, engineering training evolved entirely free from any federal authority or any central control by the states. Each institution was permitted to develop as it saw fit. In its organization, engineering education in this country is unlike that in Europe, where most schools have always been essentially national in plan and outlook, and have been controlled by public authorities and the organized professions. This freedom has proved itself a source both of strength and of weakness. It has permitted educational experimentation and innovation which, when exercised, have justified themselves abundantly through a number of major advances. On the other hand, the leaving of all initiative to individual institutions, with no co-ordination of policy, has resulted in the continued existence of a few very weak schools and the failure to devise a well-rounded national system of technical training. Engineering education has remained largely a thing apart and has not achieved in America, as in Germany, a large place in the strategy of social progress.[1]

Curriculum

This freedom from restraint has not resulted, as might have been expected, in wide differences in the 160 schools that now exist. So strong have been the power of imitation and the tendency to follow models already set up, that there is surprisingly little variation. Although 78 different curricula and "options" are offered by American schools, over 80 per cent of all students are enrolled in the five major divisions already indicated—civil, electrical, me-

[1] Wickenden, William E., "A Comparative Study of Engineering Education in the U.S. and in Europe," in Report of the Investigation of Engineering Education, 1923–1929, vol. 1, pp. 807–823, 1000–1001. See also, "A Study of Evolutionary Trends in Engineering Curricula," in Report of the Investigation of Engineering Education, 1923–1929, vol. 1, pp. 544–546; Mann, Charles R., A Study of Engineering Education, prepared for the Joint Committee on Engineering Education of the National Engineering Societies, Carnegie Foundation for the Advancement of Teaching, Bulletin 11, New York, 1918, p. 407; Baker, Ira O., "Engineering Education," in Encyclopedia Americana, vol. 10, p. 615.

chanical, chemical, and mining and metallurgical engineering. Over two-thirds are registered in the first three.[1]

The institution after which the earlier engineering colleges patterned themselves was the Rensselaer Polytechnic Institute. In 1846 when B. Franklin Greene became its head, he visited leading institutions in Europe and analyzed their curricula in the search for models. On his return he proposed a plan for a comprehensive polytechnic institute. Without doubt he was the first man in America to submit the problems of education for the technical professions to thorough investigation and analysis. What he visualized was an educational discipline entire in itself, not narrowly utilitarian but "adapted to the complete realization of true educational culture." More than any other man he gave to engineering education in America its distinctive form and character. The distinguishing feature was the parallel sequences of humanistic studies, mathematics, physical sciences, and technical subjects which have marked American engineering curricula to this day.[2]

Through evolution along the lines which Greene established, the schools have long offered humanistic and general scientific subjects which would be acceptable in a college of liberal arts as two years of work toward a bachelor's degree. The elements of general education are therefore equivalent to those still prescribed for admission to the

[1] Hammond, H. P., "Educating the Civil Engineer." In Civil Engineering, November, 1931, pp. 1269–1274.

[2] Wickenden, William E., "A Comparative Study of Engineering Education in the U.S. and in Europe." In Report of the Investigation of Engineering Education, 1923–1929, vol. 1, pp. 810–813.

majority of law and medical schools, and the organic relation between pre-technical and technical work in engineering is much closer than in most of the other professions.[1] Regardless of admission requirements, however, a large percentage of law and medical students complete the undergraduate curriculum before entering a professional school. This is not true of engineering students. Technical training remains predominantly undergraduate, and shows much less tendency than do legal and medical education to shift to a graduate level.

Although the general plan of engineering education has been well defined these many years, the curriculum has constantly received much attention, particularly in the more progressive schools. Repeated efforts have been made to keep it from becoming too crystallized and yet to weave it into a coherent structural whole. One of the major difficulties encountered has been the customary practice of striving to cover five years of work in four. This has resulted in such overcrowding of the schedule that sufficient time and emphasis could not be centered upon the more important courses. A solution of the problem is now being attempted by reducing the total number of requirements for graduation and concentrating upon fewer subjects. Many engineering teachers, however, insistently maintain that adequate preparation can never be given until the curriculum is lengthened to five years. Thus far they have had little success in putting their conviction into

[1] "A Study of Evolutionary Trends in Engineering Curricula." In Report of the Investigation of Engineering Education, 1923–1929, vol. 1, pp. 810–813.

practice. On the other hand, stress is being placed upon at least one year of graduate work for students of exceptional ability.

While the Society for the Promotion of Engineering Education was making its recent extensive study, known as the Report of the Investigation of Engineering Education, 1923–1929, it obtained statements from more than 7,000 experienced teachers and prominent members of engineering institutions concerning what they believed should be the characteristics of technical training. It seems safe to conclude that the following points, about which there was consensus of opinion, may be accepted as basic concepts in the present philosophy of engineering education:

1. Emphasis upon a moderately diversified, rather than upon a highly specialized, curriculum.
2. Emphasis upon subject matter of a scientific and broadly technical nature.
3. Inclusion of a well-defined core of subject matter required in common of all engineering students.
4. Inclusion, throughout the course, of subjects of cultural value.
5. Adequate but not predominant emphasis on the economic aspects of engineering and their relation to administration and management.
6. Coherence of arrangement and co-ordination of related subjects.
7. Thoroughness rather than completeness of detail.[1]

[1] Scott, Charles F., "A Brief: Summarizing the Results of the Investigation of Engineering Education and Related Activities." In Report of the Investigation of Engineering Education, 1923–1929, vol. 2, p. 1248.

The fifth statement deserves particular attention, for around it has centered much discussion during the past few years. Engineers, as has already been noted, are increasingly assuming administrative and executive positions of great responsibility. For such positions they need preparation, particularly in economics and the social sciences. How the curriculum may be broadened to include these extensive subjects without sacrificing any of the fundamentals has been a question. Some schools have done nothing more than to require the customary year of English and a half-year of economics. Many of the more forward-looking institutions have supplemented courses in the principles of economics with those in labor problems and business administration; history has sometimes come to include an orientation course for freshmen in the evolution of civilization; a little psychology, sociology, and political science have crept into the curriculum, generally in the form of elective courses. Some engineering teachers believe that the increased emphasis upon the social studies has been good, but cannot be carried farther without weakening the present program of general technical training. Others are convinced that the colleges should do still more to give engineers a well-rounded education. They point to the past two decades as a demonstration that society is demanding of the engineer not merely the control and utilization of the forces and materials of nature, but the application of engineering methods and techniques to the solution of problems of the social order. They conceive the function of engineering education to be much like that of legal training—a preparation whereby a man may either enter upon a technical career or may go into business or the fields of economic and social planning.

Of the many who have lately voiced the social responsibility of the engineering profession, no one has done it more eloquently than Secretary of Agriculture, Henry A. Wallace:

> It is difficult to see how the engineer and the scientist can much longer preserve a complete isolation from the economic and social world about them. A world motivated by economic individualism has repeatedly come to the edge of the abyss, and this last time possibly came within a hair's breadth of plunging over. Yet science all this time has been creating another world and another civilization that simply must be motivated by some conscious social purpose, if civilization is to endure. Science and engineering will destroy themselves and the civilization of which they are a part, unless there is built up a consciousness which is as real and definite in meeting social problems as the engineer displays when he builds his bridge. The economist and the sociologist have not created this definite reality in their approach; can you, trained in engineering and science, help in giving this thought a definite body?
>
> It seems to me that the emphasis of both engineering and science in the future must be shifted more and more toward the sympathetic understanding of the complexities of life, as contrasted with the simple mathematical, mechanical understanding of material production.[1]

The implications of Secretary Wallace's challenge of a "sympathetic understanding of the complexities of life"

[1] "The Engineering-Scientific Approach to Civilization." In Mechanical Engineering, March, 1934, pp. 132–133.

and the creation of a "definite reality" are very great. What engineering faculties can do, where so many other university professors have only partially succeeded at best, remains to be seen.

The Report of the Investigation of Engineering Education refrained from prescribing any particular courses or method of approach to this problem, maintaining that the curriculum was an open field for experimentation by the colleges. It did recommend, however, that "social and economic studies should reveal the broad interplay of social forces and also the specific economic problems and social situations in the realm of engineering." It summarized the general attitude of the Society for the Promotion of Engineering Education toward new educational trends in the words:

> Engineering education cannot be static; it has been and must continue to be an evolution. It can cope with enlarging responsibility to society and increasing exactions of professional practice by enhancing its own distinctive qualities rather than adding unrelated elements from without. Emphasis on humanistic subjects for enriching the conception of engineering and its place in the social economy, a more connected and better grounding in engineering principles, and greater capacity for self-directed work may all be gained at the expense of unrelated studies and detailed training in technique. The latter should find place in post-graduate and post-scholastic courses.[1]

[1] Scott, Charles F., "A Brief: Summarizing the Results of the Investigation of Engineering Education and Related Activities." In Report of the Investigation of Engineering Education, 1923–1929, vol. 2, pp. 1253–1254.

Technical Schools Other Than Engineering Colleges

Engineering education, as it appears in the third decade of the twentieth century, is "a complex of borrowed and indigenous elements" that have been synthesized during the course of more than a hundred years into a system. Unfortunately this system of education is largely on one level, whereas engineering is clearly a vocation on several levels. The democratic desire to give "all the boys a chance to get to the top" has resulted in a greater multiplication of engineering colleges in the United States than in any other country, and in the failure to make a rational division of the functions of technical education among different types of schools. This, in turn, has forced the colleges to assume the heavy burden of training large bodies of students. Graduates alone number about 9,000 annually. Because of the size of enrolments and the great expense of operating so many institutions, efforts to create colleges of distinctly superior scientific standards have frequently fared badly. Like other American educational institutions, the engineering school has often been judged more by the excellence of its buildings and equipment and the rate of its expansion than by the eminence of its teachers, the scientific quality of its instruction, or the merits of its research. Under such circumstances, it has done the best it could to develop a general basic education that gives the essentials of training to its matriculants.

Because attention has been focused upon collegiate instruction in engineering, trade schools and technical institutes have been largely eclipsed and graduate curricula have only recently assumed a position of importance. The distinction that is universally made abroad between preparation for the practical direction of industry and for its intellectual leadership has rarely been recognized. As a consequence, in the field of production, industry has been seriously undermanned because of the lack of technicians, while technical research and industries concerned with construction have sometimes been obliged to depend upon men educated abroad or trained in pure science.[1]

The inadequacy of the number of technical institutes is particularly serious. The difference between the situation in Europe and in the United States is easily discernible when one notes that in Great Britain there are 14 universities that award engineering degrees and more than 150 local technical institutes; in Germany there are 11 technical universities and 2 mining academies of like rank, while the number of higher industrial schools probably exceeds 100.[2] In the United States there are 160 colleges that confer degrees, but scarcely more than 30 schools of post-secondary character which train technicians for those vocations lying between the skilled crafts and the kinds of engineering work that require prolonged scientific preparation. Where technical institutes have appeared, they have been located

[1] Wickenden, William E., "A Comparative Study of Engineering Education in the U.S. and in Europe." In Report of the Investigation of Engineering Education, 1923–1929, vol. 1, pp. 808, 822, 1002.

[2] Wickenden, William E., "The Investigation of Non-College Technical Education." In Proceedings of the Society for the Promotion of Engineering Education, 1928, p. 135.

in proximity to industrial centers. This explains the fact that most of them originated in the area east of the Mississippi and north of the Ohio and Potomac Rivers. A further development of technical institutes, however, is now going on in the newer industrial areas, notably California.[1]

Among the schools that are giving excellent instruction of this type are the Wentworth Institute, the Franklin Union, and the Lowell Institute in Boston; the Bliss Electrical School in Washington; the Ohio Mechanical Institute in Cincinnati; the Rochester Athenaeum and Mechanics Institute; and the Dunwoodie Industrial Institute in Minneapolis. (The Pratt Institute of Brooklyn falls into an intermediate position between the technical institute and the engineering college. Although it is not a degree-conferring institution, its curriculum probably more closely approaches the college than the institute.) Such schools are meeting a real need in a genuinely effective way without departing from their vocational purpose or confusing the educational situation by granting degrees,[2] but their annual graduates are only about 1,500 in number. There has been a tendency, moreover, for technical institutes to become engineering colleges. This has been, in considerable part, the result of the undue emphasis that is placed upon academic degrees in the United States. Even when administrators have insisted that there should be a definite place

[1] Spahr, Robert H., "Technical Institute Education in America." In Proceedings of the Society for the Promotion of Engineering Education, 1931, p. 488.

[2] Mann, Charles R., A Study of Engineering Education, pp. 4–7.

for technical institutes, pressure such as that exerted by State Boards of Engineering Examiners has caused them to move in the direction of full collegiate training.

The curricula of technical institutes are of three rather distinct types: (1) engineering courses which parallel college courses but in briefer, more direct, intensive, and practical forms; (2) courses in the technology of specific industries; and (3) courses which prepare students for particular technical functions. All curricula are more distinctly vocational than are those of four-year engineering colleges; yet they include a substantial amount of the underlying and related sciences and usually some work in English and economics. The period of training is generally two years. The shorter the period the more rigid the schedule of studies. There are few opportunities for the student to substitute subjects or choose electives. The curriculum offered is considered the best and quickest path to a particular objective. "Doing to learn" is an important characteristic of the instruction; a considerable portion of the student's time in school is devoted to practice in laboratories, shops, drawing, and design.

Students are admitted to the technical institutes primarily on evidence of their capacity, interest, and in some instances future employability, rather than on presentation of formal scholastic credentials. The courses are devised to meet the needs of those having a fairly settled vocational aim; those who, for financial reasons, cannot spend four years or more in preparation for remunerative employment; and those of mature age who, from practical experience, have discovered their technical bents and have realized the need for systematic technical education.

In his recent study of technical institutes, Robert Spahr[1] sought to determine the need of business and industry for men thus trained. Employers were asked to study and analyze their situation in terms of ratios of technical institute graduates to four-year engineering college graduates. Industry in general thought that if it were to operate efficiently, it should have 2.7 technical institute graduates to one four-year graduate. Manufacturing in particular indicated that from 6 to 8.3 per cent of its total employes should be technical institute graduates, from 2.2 to 3 per cent should be four-year graduates, and about 15 per cent should be trained in elementary manual and industrial courses.

In order to learn the attitude of industry toward men trained in these intermediate schools, an inquiry was made of 15 representative companies that were known to have employed both technical institute and college graduates. These companies were asked whether, from their experience, they believed that there is a type of education, intermediate in position between vocational and trade schools on the one hand and engineering college education on the other, that needs to be encouraged and developed in America. They replied unanimously in the affirmative and defined the purposes of such preparation as follows: to qualify men for supervisory positions in operating depart-

[1] "Technical Institute Education in America." In Proceedings of the Society for the Promotion of Engineering Education, 1931, pp. 494–495.

ments; for technical services such as drafting, designing, testing, inspection; and for commercial positions relating to the sale of technical products and services.

It is a significant fact that college graduates do not enter the production end of industry in large numbers, while graduates of technical institutes do. Industrial employers contend that there is not only a vital need for technically trained men in this field, but that there are excellent opportunities as well. Spahr concluded that fifteen to twenty thousand men could probably be absorbed annually in manufacturing alone. Although the estimates from public utilities and transportation industries were less comprehensive, the trend was the same. So clear-cut is the case in favor of these intermediate schools, that William E. Wickenden is firmly of the opinion that the industrial interests of the country can be served better by a great expansion of technical institutes than by a further multiplication of engineering colleges.[1]

Graduate Training

Just as engineering education has been insufficiently developed through the medium of technical institutes, so graduate work in engineering was long neglected. Although the first earned doctorate in engineering of which there is any record was awarded by Yale University in 1873, and the first master's degree was conferred by Iowa State College in 1879, the number of colleges that gave

[1] "Summary of the Study of Technical Institutes." In Transactions of the American Society of Mechanical Engineers, vol. 52, part 2 (1930), p. 63.

advanced degrees and the number of men who received them during the eighteen hundreds was very small. After the turn of the century the offering of work beyond the baccalaureate began to spread rapidly. By 1920 at least 40 institutions had granted master's degrees and 11 doctor's degrees.

During the past fifteen years, graduate work has experienced a phenomenal growth. In 1924–1925 advanced curricula were maintained by 81 institutions, and the total enrolment of graduate students was approximately 1,000. A single school, however, had 20 per cent of all the graduate students and 10 had 87 per cent. By 1933–1934, 86 colleges and universities were offering graduate work and the number of students had grown to 2,756. Although there was still a considerable concentration of matriculants in a few institutions, enrolments were far more evenly distributed. Four hundred and fifty persons were working for the Ph.D. or Sc.D. degree in the 30 institutions that provided courses leading to the doctorate. During the year these 86 engineering schools conferred 1,071 master's degrees and 126 doctor's degrees.

Although unemployment resulting from the economic depression has caused many men to return to the colleges for additional study, there is a rapidly growing tendency in engineering to demand prolonged professional training as preparation for teaching, research, and certain types of executive positions. This tendency is becoming so strong that schools foresee little recession in the number of graduate students even if the demand for engineers once more becomes urgent. As a result of the increasing emphasis upon advanced work, a large number of schools have noticeably improved both the quantity and the quality of their graduate courses. This has been particularly true in those institutions with the more exceptional laboratory facilities and teaching staffs. Expansion has been so rapid, however, that the Committee on Graduate Study of the Society for the Promotion of Engineering Education[1] has recently recommended that it would be wise for further development, particularly of curricula leading to the doctorate, to proceed more slowly. Much of the recent growth has occurred at a time when institutions have been struggling under seriously adverse conditions. It is believed that engineering education should now consolidate the gains it has made and strengthen its position in the field of graduate work before attempting further extensive advance.

Engineering Students

In 1930–1931, 73,000 students were enrolled in degree-conferring schools. The number dropped appreciably during the next three years, but a marked gain was noted in the fall of 1934 and again in 1935 and 1936.

Since both engineering education and subsequent professional activities are conditioned largely by the type of men who enter the colleges, it is essential to know something of their background. About seven-eighths of them prepare for academic work in public high schools. Eighty-four per cent live within the state whose institution they

[1] Report of Progress, June, 1935. Mimeographed pamphlet.

attend, and only 15 per cent migrate to other states. Slightly more than 1 per cent come from foreign countries. The American student is at a great disadvantage over the European student who, by the very process of being admitted to a secondary school, enters a carefully selected group where intellectual and cultural standards are high, where achievement is superior to that in the United States, and where preparation for the professional schools is long and exacting.[1]

When one considers American laxness in educational matters, it is not surprising that of the 8,728 students admitted to 52 engineering institutions in 1924, 20 per cent were classified as "conditioned students." Sixty-seven per cent of the latter group were deficient in mathematics, and 21 per cent in other sciences. Although the requirements for admission to engineering schools are rather generally uniform, and, in the opinion of the Committee on Admissions and Eliminations of Engineering Students, are as high as the present situation warrants, the admission of students deficient in one or more subjects nullifies the real and potent influence that a fixed standard might exert.[2]

Because so many students enter engineering schools with conditions, it is not strange that the percentage of failures is very high. Failures are due to many causes, to be sure,

[1] Wickenden, William E., "A Comparative Study of Engineering Education in the U.S. and in Europe." In Report of the Investigation of Engineering Education, 1923–1929, vol. 1, p. 1003.

[2] "Report of Committee on Admissions and Eliminations of Engineering Students, May 1, 1925." In Proceedings of the Society for the Promotion of Engineering Education, 1926, pp. 49–51.

but of the most important—poor preparation, lack of ability, and lack of interest—the first certainly plays a very large role. In 1924–1925 eliminations among students admitted with deficiencies in mathematics were 60 per cent greater than among those admitted with clear records.

The large number of failures in engineering subjects is a very serious problem, as it constitutes a waste in time, energy, and money for parents, students, and schools. Of every 100 students admitted to engineering colleges approximately 38 are graduated, and of these 38 only 28 complete the course in the specified period. The ratio of graduations to admissions is probably lower than in any other division of university work.[1] The Committee on Admissions and Eliminations asserts that the mortality rate is high and steadily advancing. It believes that eliminations will continue to grow in direct proportion to the failure of the high school to give training in essential preparatory work, the increase of distracting influences outside the classroom during the high school and college period, and the lack of balance and stimulus in engineering curricula.[2]

Engineering Faculties

Inasmuch as the success or failure of engineers depends to a considerable extent upon the kind of instruction that they have received while attending professional schools,

[1] Hammond, H. P., "Summary of the Fact-Gathering Stages of the Investigation of Engineering Education." In Proceedings of the Society for the Promotion of Engineering Education, 1927, pp. 57–58.

[2] "Report of the Committee on Admissions and Eliminations of Engineering Students, May 1, 1925." In Proceedings of the Society for the Promotion of Engineering Education, 1926, pp. 52–54.

much attention is being given to the question of the efficiency of engineering faculties and methods of teaching.

It was Dr. Wickenden's conclusion, in 1925, as the result of his visit to ten European countries, that the engineering professor occupied a place of higher prestige and influence in the Old World than in the United States. He believed that many American teachers were industriously attempting a task for which they were inadequately prepared by scientific training, by professional experience, or by broad personal culture; and that the technical professions and industries had not attached enough importance upon placing and keeping men of the greatest ability at the chief source of their recruitment. The situation has changed appreciably in the past few years. Engineering colleges are now succeeding in getting men who are far better prepared for teaching than ever before. It is still difficult, however, to uphold standards among teachers that are well above those prevailing in the profession at large, when teaching positions are not invested with high prestige, wide freedom, and reasonable affluence.[1] In none of these three respects has the average engineering school achieved nearly as much as is desirable. Teaching loads are heavy, more than half of the colleges make no provision for sabbatical leave, and salaries are considerably below those earned by engineers in industry.[2]

[1] Wickenden, William E., "A Comparative Study of Engineering Education in the U.S. and in Europe." In Report of the Investigation of Engineering Education, 1923–1929, vol. 1, p. 1010.

[2] Hammond, H. P., "Summary of the Fact-Gathering Stages of the Investigation of Engineering Education." In Proceedings of the Society for the Promotion of Engineering Education, 1927, p. 59.

In spite of these problems, engineering teaching compares very favorably with that in any undergraduate curriculum, and probably with much of the teaching in professional schools that more nearly approach the graduate level. The shortcomings of engineering instruction are shared by all branches of teaching. Two facts must constantly be kept in mind: first, American instructors in general rarely enjoy the social distinction accorded their colleagues in most European countries; second, all but a few distinguished universities are constantly faced with the problem of how to attract men and women of notable ability and extensive preparation. The very individuals who could make the finest contributions to education are the ones most likely to be offered opportunities outside the professional school that they cannot afford to refuse. The engineering college suffers, as do other academic institutions, by these unfortunate realities.

As an inevitable outcome of too much teaching being required of teachers and the failure to recognize that a college has a second function scarcely less important than instruction, engineering faculties have not been active in research. The Investigation of Engineering Education revealed that the average teacher was devoting only 1.3 hours a week to research projects. Many of the faculty members of the stronger schools were able to spend much more time, but in the smaller institutions accomplishment was frequently negligible.[1] During the year 1924–1925, engineering col-

[1] "Data Relating to Engineering Teaching Personnel." In Proceedings of the Society for the Promotion of Engineering Education, 1927, p. 228.

leges in the United States spent approximately $1,500,000 on research. If this seems like a large amount, it must be remembered that it was but 5 per cent of the amount expended for undergraduate instruction. Furthermore, 90 per cent of the expenditures for research were made by 22 institutions. While the extent and value of research work cannot be stated entirely in terms of dollars, it is likely that the figures give a fair indication of the place which research held in technical schools. Research is gradually growing both in quantity and quality, but it is still definitely a subordinate activity.[1]

It is only in the last two or three decades that research has been regarded as more than an incident in the work of our engineering colleges. There are still relatively few men of high research capabilities in our professorial chairs; industry has requisitioned many of the most fertile for her own fast-growing research establishments; and until quite recently there has been far greater incentive to text-book writing and to incidental practice than to research. Research personnel cannot be improvised; that of the German institutions is the product of a century of cultivation and selection, backed up by a powerful tradition. With the fullest allowances for the difficulties of pioneering, one cannot say that the matter of research has been handled by the engineering colleges in a highly statesmanlike manner. It was only rarely that the growing need was anticipated. Industry, meanwhile, having discovered the potency of research as a competitive weapon and a publicity asset, has become definitely committed to research on its own account. The

[1] Hammond, H. P., "Summary of the Fact-Gathering Stages of the Investigation of Engineering Education." In Proceedings of the Society for the Promotion of Engineering Education, 1927, pp. 62–63.

opportunity to make the engineering colleges the chief centers of technical research seems to have passed.[1]

Because engineering research did not grow up as an integral part of the colleges, but developed in them later and less effectively than in industry, there has been much discussion of the possible wisdom of leaving it to the commercial and industrial laboratories. The attitude is being insistently expressed, however, that there is a large amount of research of great economic importance which could be carried on to better advantage by the colleges than by commercial institutions. Convinced of the validity of this attitude, there has been organized under the National Research Council a Committee on Bridging the Gap between Industry and the Universities. Its function is to list and evaluate the research facilities and capacities of the engineering colleges which might be used co-operatively with industry or might be subsidized to undertake specific problems of a more theoretical nature than are those usually studied in industrial laboratories.

There has been one particularly encouraging movement in the university research field: the evolution of engineering experiment stations. The first station was established at the University of Illinois in 1903 for the purpose of definitely organizing and putting upon a more satisfactory basis the engineering research being carried on in that institution. A few months later a similar station was estab-

[1] Wickenden, William E., "A Comparative Study of Engineering Education in the U.S. and in Europe." In Report of the Investigation of Engineering Education, 1923–1929, vol. 1, pp. 1008–1009.

lished at Iowa State College. Institutions having strong agricultural experiment stations were among the first to recognize the importance of organizing their engineering and industrial research in a similar fashion. At least 29 land grant colleges, besides several state universities and privately endowed engineering colleges, have established such stations. The success which has attended them has fully justified the belief that they can render a service to engineering and industrial groups comparable to that rendered to farmers by agricultural experiment stations.[1]

The foregoing facts convey the idea that there are hopeful developments in engineering research, but that thus far investigation has been largely confined to a few colleges. In reality, however, although members of faculties have not contributed widely to technical research within their institutions, many of them have carried on research outside the college in connection with consulting practice. The extent of this practice is not known, but it is considerable. It is justified on the basis that teaching is generally improved by it in spite of the time taken away from academic duties, and because it serves to augment insufficient salaries. Teachers are permitted to engage in practice during term time in a very large percentage of engineering schools. Many institutions encourage it, some tolerate it, and only a few forbid it.[2]

[1] Seaton, R. A., "How Industry Can Co-operate with Engineering Colleges in Furthering Research." In Proceedings of the Society for the Promotion of Engineering Education, 1926, p. 206.

[2] "Data Relating to Engineering Teaching Personnel." In Proceedings of the Society for the Promotion of Engineering Education, 1927, p. 299.

Salaries of Engineering Teachers

References have already indicated that salaries of engineering teachers have been insufficient to attract enough really able men. So important is this question to the future of professional training that more attention must be given to it. Statistics readily demonstrate the discrepancy between the income of engineers in teaching and those in practice.[1] A study of earnings in 1924 and 1925 revealed that when the two groups were entering upon their ca-

TABLE 1.—ANNUAL EARNINGS OF ENGINEERING TEACHERS, 1925, AND OF ENGINEERING GRADUATES IN PRACTICE, 1924, BY YEARS SINCE GRADUATION

Values taken from smooth curves

Years since graduation	Median salary of teachers	Median total earned income of teachers	Median total earned income of graduates	Ratio: salary of teachers to earnings of graduates	Ratio: earnings of teachers to earnings of graduates
0[a]	$1,500	$1,500	$1,475	1.02	1.02
1	1,500	1,750	1,800	.83	.97
2	1,700	1,900	2,100	.81	.90
5	2,000	2,350	2,860	.70	.82
10	2,550	3,100	4,000	.64	.78
15	3,100	3,825	5,000	.62	.77
20	3,600	4,500	5,900	.61	.76
30	4,225	5,550	7,500	.56	.74

[a] First appointment.

[1] Warren, Charles H., "Engineering Teaching Personnel." In Report of the Investigation of Engineering Education, vol. 1, p. 310.

reers, the salary of the teacher exceeded that of the graduate in practice. After the first year, however, the former earned steadily less than the man in industry until, in the thirtieth year, the median total earnings of teachers were only 74 per cent as great as those of graduates in practice. If academic salaries were used as the sole basis for comparison, the status of the teacher was still less favorable.

TABLE 2.—ANNUAL SALARIES OF ENGINEERING TEACHERS IN 1925 COMPARED WITH SCALE PROPOSED BY COMMITTEE ON TEACHING PERSONNEL

Teaching rank	Salaries in 1925		Proposed salaries	
	Minimum	Maximum	Minimum	Maximum
Instructor	$ 900	$3,000	$1,500	$ 3,500
Assistant professor	1,500	5,000	4,000	5,500
Associate professor	2,000	6,000	6,000	6,500
Professor	2,500	7,500	7,500	12,000

It was found, moreover, that in 69 representative institutions the median salary of instructors in 1925 was only $2,000, and that of assistant professors was $2,700. Associate professors received $3,000, and full professors $4,000. In the face of facts such as these, it was apparent that it would be impossible to raise the quality of instruction to the level which the importance of engineering warranted unless remuneration could be greatly increased. In

1926 the Committee on Teaching Personnel recommended a scale of salaries shown in Table 2, which seemed to be commensurate with the needs of the situation.[1] Although the Committee realized that this scale was beyond the possibility of immediate realization in many institutions, Hammond emphasized the fact that the maximum salaries recommended were being paid to some teachers in a small but growing number of universities, particularly in medical schools.

In 1930 mechanical engineers made an investigation of the earnings of their group. In spite of all the publicity that had attended the reports of the study just reviewed, salaries of mechanical engineering teachers were still much lower than those of engineers in industry. Median academic salaries began to fall below the median for industry when the teacher was twenty-eight years old. When he was fifty-five his salary was approximately $2,000 less. After fifty-five he had a relative advantage over the man in technical work and his situation showed a slight improvement.[2]

In the past few years there have been reductions, sometimes of a drastic nature, in salaries in many universities. The teacher, however, has been better off than have thousands of engineers who have either been unemployed for a long time or have earned very little. As the demand for

[1] Hammond, H. P., "Summary of the Fact-Gathering Stages of the Investigation of Engineering Education." In Proceedings of the Society for the Promotion of Engineering Education, 1927, pp. 60–61.

[2] Committee on the Economic Status of the Engineer, "1930 Earnings of Mechanical Engineers." In Mechanical Engineering, September, 1931, p. 654.

engineers once more increases, the discrepancy is likely to become again marked, although it may be less so than in the past, particularly if a considerable proportion of engineers are in government employ.

NATIONAL ASSOCIATIONS

Their Number and Nature

It has been said that "there has been perpetrated, on the average, nearly one new association, council, institute, organization, or society representing some branch or branches of engineering or applied science for each intervening year between 1848 and 1933."[1] This statement appears to be true even when one considers only those bodies which have, at some time in their history, assumed the aspect of national rather than sectional importance. Obviously, out of all this welter of societies, only a few can be chosen for discussion. Emphasis will be centered upon seven large and truly national associations and one Council composed of representatives of the seven. These organizations have displayed leadership of great importance in the cause of advancing professional standards.

The first one, the American Society of Civil Engineers, was founded as long ago as 1852. The American Institute of Mining and Metallurgical Engineers came into existence in 1871, the American Society of Mechanical Engineers in 1880, and the American Institute of Electrical Engineers in 1884. These four national organizations

[1] "Engineering Societies: Their Multiplicity, Their Relatives, Their Duplication." In The Technology Review, July, 1933, p. 330.

which represent well-defined branches of engineering, are called the Founder Societies. They are loosely united through relations with a property-holding organization known as United Engineering Trustees, Incorporated; through the merger of their reference libraries to form the Engineering Societies Library; and through the establishment of a joint Employment Service, and a research organization called the Engineering Foundation. Besides these four Founder Societies, a fifth organization established in 1908, the American Institute of Chemical Engineers, represents another major branch of engineering. The Society for the Promotion of Engineering Education was created in 1893. It is composed of engineering teachers and representatives of engineering schools and industries interested in advancing the standards of professional training. The National Council of State Boards of Engineering Examiners which has been in existence since 1920 is concerned with the certification of engineers. In 1932 the four Founder Societies and the three last named associations joined in the formation of the Engineers' Council for Professional Development.[1]

Within these eight organizations are represented not only the broad divisions of engineering, but professional education, licensing, and a new movement designed to advance the status of the professional engineer. A large majority of the many other engineering associations consist of groups organized along functional lines to further a

[1] Reed, Alfred Z., Review of Legal Education in the U.S. and Canada for the year 1934. Carnegie Foundation for the Advancement of Teaching, 1935, pp. 23–25.

special purpose or the interests of a particular industry. Of the few which fall outside these classifications, the National Society of Professional Engineers, established in 1934, deserves note.[1] Its membership is limited exclusively to those who have been legally registered or certified. Its purpose is to protect the professional engineer who has spent many years in study, training, and experience as preparation for his career. Emphasis is centered upon the advancement of his social and economic welfare. Its goal is an Engineers' Registration Law and a State Society of Professional Engineers in every state, and the enrolment of all professional engineers as members of the national and constituent state societies. The American Engineer is the official publication of the Society.

Examples of National Associations

American Society of Civil Engineers. Since all five national associations representing the major divisions of engineering have similar types of organization, a description of the oldest, the American Society of Civil Engineers, will serve for the other four. According to its constitution:

> The objects of the Society shall be the advancement of the sciences of engineering and architecture in their several branches, the professional improvement of its members, the encouragement of intercourse between men of practical science, and the establishment of a central point of reference and union for its members.

[1] National Society of Professional Engineers, Officers, Objectives, Constitution, Ideals and Purposes; Steinman, D. B., Engineers' Registration and Related Problems of the Profession (pamphlets published by the Society).

Membership is of four grades. In order to be eligible to become a Full Member, the engineer must be qualified to design as well as to direct engineering work. He must be thirty-five years of age or older, have had twelve years of active practice, and have had responsible charge of work for at least five years. (Graduation from a school of engineering of recognized reputation is considered the equivalent of four years of active practice for all grades of membership.) An Associate Member must be qualified to direct work, must be twenty-seven years of age, have had eight years of active practice, and must have been in responsible charge of work for one year. A Junior must be qualified for sub-professional work, must be at least twenty years of age, and have spent four years in practice. Membership lapses when he is thirty-three unless he has been transferred to a higher grade. An Affiliate is one who is qualified by scientific training or practical experience to cooperate with engineers. He must be thirty-five, have had twelve years of active practice, and five in responsible charge of work.

Four general meetings are held during the year; the annual meeting in January in New York City, an annual convention during the summer, and spring and fall meetings in different sections of the country. The Society issues regularly three technical publications: Proceedings, Transactions, and Civil Engineering. The first and third appear monthly. The annual Transactions contains technical matter which has appeared serially in the Proceedings, collated to make a permanent record.

The general administration of the Society is carried on by a Board of Direction assisted by six standing committees. Divisions may be organized for the consideration of any engineering, scientific, or professional subject upon the written request of no fewer than 20 members. The names of the technical divisions, of which there are ten at present, provide some clue to the broad scope of the program of the Society. They are:

City Planning	Power
Construction	Sanitary
Engineering-Economics and Finance	Structural
Highway	Surveying and Mapping
Irrigation	Waterways

Within the national Society with its membership of more than 15,000, there are some 56 local sections to which above 6,000 belong. The work of these sections is carried on by about 300 committees. There are also more than 100 student chapters in engineering colleges with an enrolment of about 4,000.[1] These figures alone show how extensive is the influence of the organization geographically. In the exploration of the scope and the subject matter of civil engineering and in the insistence upon high standards, the Society has accomplished much, and it has attempted through its local bodies to provide a medium whereby civil engineers in all parts of the United States may be participants in the processes of investigation, study, and professional development.

[1] American Society of Civil Engineers, Year Book Number 1934; American Society of Civil Engineers, Aims and Activities, 1931.

Society for the Promotion of Engineering Education. This very influential organization was the outgrowth of a Congress of Engineers held at the World's Columbian Exposition in Chicago in 1893. Teachers of engineering formed one division of the Congress. Attendance and interest at their meeting were so encouraging that it was voted to establish a permanent organization. A committee appointed to formulate plans presented a constitution, which has continued substantially unchanged as the fundamental law of the Society.[1] According to this constitution, the objects of the Society are "the promotion of the highest ideals in the conduct of engineering education with respect to administration, curriculum, and teaching work, and the maintenance of a high professional standard among its members."

Membership in the Society is of two classes: individual and institutional. In January, 1934, there were 2,271 of the former class and 121 of the latter. Individual membership consists of those who occupy or have occupied responsible positions in engineering instruction, and practitioners or others interested in engineering education. Institutional members are educational institutions giving instruction in engineering. One regularly appointed delegate represents each institutional member.[2] The principle of institutional membership in the Society is new. After more than thirty years of existence as an association com-

[1] "Origin of the Society." In Bulletin of the Society for the Promotion of Engineering Education, August, 1914, pp. 3–4.

[2] Society for the Promotion of Engineering Education, Yearbook, 1934, p. 150.

posed of individuals, the limitations of individual effort became increasingly apparent. It seemed advisable for the Society to enlarge its functions in an attempt to promote more effectively the common interests of the colleges, to stimulate them to a concerted attack upon their problems, and to bring them into more active relationship with the engineering profession and the industries. Hence, in 1927, an Institutional Division was created, co-ordinate with the Division of Individual Members. It was proposed that this central organization should ultimately include a Board of Direction, a permanent staff organization, a joint liaison board with the engineering profession and industries, and an Endowed Foundation for Engineering Education.[1]

A section of the Society may be formed by members in two or more institutions, or by members within a prescribed territory. A branch may be established in any institution. The purpose of these sections of which there are now 14 and of the 11 branches is to extend the interest in, and the discussion of, questions relating to the teaching of engineering students, and to bring to the Society at large, through their publications, institutional activities which will be serviceable to the members of the national association.[2] Dean H. S. Rogers, writing in 1932, emphasized the importance of sections and branches in providing

[1] Wickenden, William E., "Report on Future Organization and Activity." In Proceedings of the Society for the Promotion of Engineering Education, 1928, pp. 161–174.

[2] "Constitution of the Society for the Promotion of Engineering Education." In Journal of Engineering Education, January, 1934, pp. 160–164.

an opportunity for the advancement of engineering education. He stated that although only one-tenth to one-seventh of the membership of the Society is able to attend the annual convention, 62 per cent belong to the local associations—the percentage may now be higher. Thus they have group contacts with others interested in educational questions.[1]

The monthly Journal of Engineering Education and the Year Book are the formal publications of the Society. The former contains the proceedings of the annual convention, and articles submitted to and approved by the Publication Committee.

The range of the work of the Society is so wide that it has probably influenced instruction in every engineering college in the country. Such committees as those on Relationship of the Society to Engineering Societies, Comprehensive Examinations, Classification of Engineering Colleges, Junior Colleges, and Graduate Work afford opportunity for study and exchange of views. Divisions on engineering drawing, mechanics, and physics have served as a clearing house for the best thought of engineering teachers.[2] Besides the customary program of the Society, there have been two undertakings of very great significance which it has sponsored. The first of these was its comprehensive surveys of engineering education; the second its summer schools for engineering teachers.

A preliminary step toward a detailed study of profes-

[1] "Sections and Branches Vitalize Society Membership." In Journal of Engineering Education, December, 1932, p. 235.
[2] *Ibid.*

sional education was taken in 1907 when the Society invited a group of other engineering societies to join with it in an extended inquiry into all branches of engineering education. Responsibility for this project was later assumed by the Carnegie Foundation for the Advancement of Teaching, and resulted in the report of Dr. C. R. Mann entitled A Study of Engineering Education. Appearing as the publication did in 1918, countless problems connected with the World War made the moment inauspicious for fundamental changes in professional training. In 1922 the Society realized the need for and the possibility of collective effort and undertook to organize a comprehensive investigation of "the objects of engineering education and the fitness of the present-day curriculum." This exhaustive study, to which numerous references have already been made, was planned on the basis of a five-year program but extended beyond that time. A grant was obtained from the Carnegie Corporation to finance the work. It was not an external critical investigation but a co-operative endeavor in which 138 engineering colleges in the United States and Canada, through special committees or correspondents of their faculties, participated in an extended series of studies. The result, as published in numerous bulletins and finally in two stout volumes entitled, Report of the Investigation, 1923–1929,[1] proved to be one of the best group surveys ever made of professional training. It dealt with such a broad range of subjects as: the engineering student, the

[1] Published by the Society for the Promotion of Engineering Education, Pittsburgh, 1930, vol. 1; 1934, vol. 2.

teacher, the curriculum and methods of instruction, graduate work, the co-operative plan and costs of engineering education, technical institutes, and a comparison of engineering education in the United States and Europe.

The second undertaking of the Society which proved to be of exceptional value was the operation of annual summer schools from 1927 to 1933. Of the various ways whereby engineering education might be improved, the most clearly defined appeared to be through better teaching. In order to raise the level of instruction offered by men already engaged in teaching, the summer school project was initiated. Teachers of a particular subject or branch of engineering were invited to come together for a three weeks' session. Programs included lectures, model teaching exercises, laboratory and lecture room demonstrations, seminars, and work carried out by committees or members of the groups. Teaching methods were stressed at all points in the program; subject matter was considered chiefly in its relation to method. At each session, advanced phases of the subject under consideration were presented for the purpose of stimulating interest and promoting further study. Twelve sessions were held during the six years. Two were devoted to mechanics, and one to each of the following: mechanical, electrical, civil, chemical, mining and metallurgical engineering, engineering drawing, physics, mathematics, economics, and English. The average enrolment was 60, representing 41 institutions. The staff averaged 32.

Unfortunately the summer school was not able to continue after 1933 on account of lack of funds. A plan was devised in 1934, however, whereby conferences on many phases of engineering education were held for two and a half days preceding the opening of the annual convention of the Society. These conferences were so successful that they are likely to become yearly events. They are not a substitute for a three weeks' session, but they are stimulating and informative and are accessible to larger numbers than were able to attend the school.[1]

National Council of State Boards of Engineering Examiners. In 1920 members from seven state boards of engineering examiners met in Chicago to effect a permanent organization which would interest itself in uniformity of practice in the examination and registration of engineers. By 1935 the boards of 29 states and two possessions belonged to the National Council of State Boards of Engineering Examiners, which represented approximately 40,000 registered engineers. (Six other states and one possession had required the registration of engineers, and the enactment of registration laws was being promoted in nine states and the District of Columbia.)

With the growth of the Council, the concept of the scope of its responsibilities has gradually become enlarged. It now defines its purpose in the words, "to promote the public welfare by improvement of professional engineering standards through uniform administration of State Engi-

[1] Scott, Charles F., "A Brief: Summarizing the Results of the Investigation of Engineering Education and Related Activities." In Report of the Investigation of Engineering Education, 1923–1929, vol. 2, pp. 1260–1262.

neering Registration Laws, the facilitating of reciprocal relations between state boards, and by defining and maintaining National Qualifications for Registration." A brief survey of the duties of two committees and a bureau of the Council will indicate methods selected for achieving this purpose.

The Committee on Accredited Engineering Schools keeps a record of all engineering and technical schools in the United States, and reports to the Council at its annual meeting concerning those institutions which may be accepted as accredited institutions under the various state acts authorizing state boards of examiners. It is probable that the Council will decide to utilize lists of accredited schools prepared by the Engineers' Council for Professional Development as soon as they become available. Thus it will be spared a heavy task. The Committee on Uniform Examinations for Registration investigates the examinations for registration in the various states, compiles such records as may be advisable, and makes recommendations to the Council in order that standards of examinations may become as uniform as possible in all states.[1]

The National Bureau of Engineering Registration was established by the Council primarily as a medium whereby professional engineers who wish to practice in more than one state may secure a certificate of qualification that will

[1] "Constitution and By-Laws of National Council of State Boards of Engineering Examiners," in Proceedings of the National Council of State Boards of Engineering Examiners, 1929, p. 65, and 1933, pp. 133–143; National Council of State Boards of Engineering Examiners: Annual Report of Executive Secretary, October 23, 1935, and National Bureau of Engineering Registration, Bulletin of Information, November, 1935.

entitle them to engage in such practice without being obliged to register in each state that they enter. The certificate of qualification is issued to those applicants who can comply with one of the three following sets of minimum requirements: graduation from an engineering course of four or more years in a school approved by the Bureau, plus at least four years of active practice in engineering work of a character which indicates that the applicant is competent to be placed in responsible charge of such work; or successful completion of an examination showing that knowledge and skill approximate those attained through graduation from an engineering college, plus at least eight years of active practice such as the above; or twelve or more years of practice of a type indicating that the applicant is qualified to design or to supervise construction or engineering works and has had responsible charge of important engineering work for at least five years, and is not less than thirty-five years of age.[1]

Application for relatively few certificates has been made thus far. This is due partly to the fact that the Bureau has not been long established, partly to the depression which has materially decreased opportunities for an engineer to practice in several states, and partly to the newness of the whole concept of registration. In view of the progress which the state registration movement has made in the past few years, however, it is almost certain to continue, and probably at an accelerated pace. Consequently the

[1] "National Bureau of Engineering Registration." In Journal of Engineering Education, December, 1933, pp. 343–347.

work of the National Council and its Bureau are of real significance as a foundation for the standardizing of registration and for assisting the individual applicant.

Of particular importance are the Bureau's requirements for obtaining the certificate of qualification. The question of what criteria shall be utilized for defining the term, professional engineer, has long been a problem to all engineers concerned with vocational standards. These requirements are ones that have gradually been evolved by various engineering groups, and are now insisted upon by the Bureau, when issuing certificates, as representing the minimum of education and experience that a man must have to become a professional engineer. Graduation from an approved engineering school is definitely considered the most satisfactory first step toward professionalism, and the enrolments of the 160 institutions indicate how extensively it has become the accepted method. Provision is still made, however, whereby those who have not had such an experience may enter the professional ranks. Neither the Bureau nor the profession at large places anything like the degree of insistence upon formal training that the medical profession does. When registration has been longer established, eligibility will probably be limited to those who have a degree plus the requisite amount of practice, or to those who substitute an examination for the degree. Active practice, no matter of how long duration, will not of itself be considered adequate proof of competency.

In the concept that training in a school is only the first step toward registration, state boards of engineering examiners depart somewhat from the practice of boards representing a few of the other professions. Although it is true that 18 states will not allow physicians to practice until they have completed a one-year internship,[1] and four states require that the prospective lawyer spend from six months to one year in a law office,[2] the large majority license physicians and lawyers upon the successful completion of the state board examinations, which may be taken immediately after graduation from a professional school. Engineers may still enter practice in 13 states without being registered, inasmuch as the states have been less exigent in their demands upon this group. It is the consensus of opinion of the National Council of State Boards of Engineering Examiners and of the profession, however, that formal engineering education which is so largely undergraduate is not sufficient for the development of a professional engineer. It must be supplemented by a period of active practice. This point of view will probably prevail in other states as registration acts are voted by the legislatures.

Engineers' Council for Professional Development. As has already been mentioned, the Engineers' Council for Professional Development is a joint body created by seven of the national organizations: the five societies that have grown up around the major branches of engineering, the Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Ex-

[1] "Medical Education in the U.S. and Canada." In Journal of the American Medical Association, August 25, 1934, p. 572.

[2] Reed, Alfred Z., Review of Legal Education in the U.S. and Canada for the Year 1934. Carnegie Foundation for the Advancement of Teaching, New York, 1935, table opposite p. 36.

aminers. It consists of 21 members, three being appointed by each of these seven bodies. Thus its constituency represents the professional and technical, the educational, and the legal aspects of engineering. The objective of the Council is the enhancement of the professional status of the engineer. "To this end it aims to co-ordinate and promote efforts and aspirations directed toward higher professional standards of education and practice, greater solidarity of the profession, and greater effectiveness in dealing with technical, social and economic problems." So ambitious is this goal that the Council realized it would be largely unattainable for many years to come, and consequently set as an immediate purpose "the development of a system whereby the progress of the young engineer toward professional standing can be recognized by the public, by the profession, and by the man himself, through the development of technical and other qualifications which will enable him to meet minimum professional standards."

Four standing committees are striving toward the realization of this purpose. It is the function of the Committee on Student Selection and Guidance to recommend sources of information for promising secondary students, parents, teachers, and counselors, which describe the qualities and aptitudes that contribute to the successful pursuit of an engineering education, the quality and quantity of the major subjects offered in college, the technical positions occupied by engineering graduates, the supervisory and executive positions into which they may progress, the value of a technical education as preparation for industrial and business vocations, and the activities and responsibilities of the professional engineer. It is also the duty of this Committee, in consultation with the National Occupational Council and other bodies, to see that necessary vocational literature is prepared and made available to the engineering schools. At present the Committee is circulating a 60-page pamphlet prepared by the Engineering Foundation entitled, Engineering: A Career–A Culture. This pamphlet describes the aptitudes desired of the engineering student, and the type of work performed by civil, electrical, mechanical, chemical, and mining and metallurgical engineers. Under the stimulus of local engineering sections, co-operative relations are being established with such groups as secondary school teachers, parents, and the Boy Scouts of America in the hope that facilities for guidance will be increased and that, as a result, young men of real engineering ability may be directed toward the professional schools, while others may be discouraged from matriculation.

To the Committee on Engineering Schools has been delegated the task of investigating degree-conferring colleges and submitting a list of those adequately prepared to offer sound and comprehensive instruction in the various major curricula. The Committee believes that there is basis for difference of opinion concerning the theoretical desirability of accrediting institutions. Since accrediting is now being done, however, by several agencies that are not representative of the entire profession and that have not attempted to co-ordinate their efforts, the Committee assumed this responsibility. It hopes that its list of approved institutions, when ready, will be uniformly accepted by the constituent bodies of the Council, thus relieving societies and states of the necessity of duplicating the work and freeing the schools from the annoyance of numerous examinations and questionnaires. Plans will probably be made later whereby the list may be revised at regular intervals.

Information on important aspects of organization, administration, curricula, and standards in each school have been assembled. Institutions in New England and the Middle Atlantic states have been visited by members of the Committee, and these visits will soon be extended to include the entire country. Upon completion of this part of the program, all data will be presented to the Council for final action. Because of the variety of types of engineering training and the specialized character of many schools, accrediting will be done on the basis of six major curricula, and allowance will be made for still others. Absolute minimum standards are being avoided lest they become fetters to future progress.

Since it is the conviction of the Council that a man has not had the preparation or experience necessary to warrant his being granted full professional status until some years after graduation from an engineering college, the Committee on Professional Training has been entrusted with the duty of devising ways of aiding him in his technical and cultural developments during the early period of his practice. As a first step, it prepared a pamphlet of Suggestion for Junior Engineers that contained a questionnaire designed to help the individual in appraising himself in relation to his occupation, and an annotated list of books selected from ten major fields of knowledge. The latter was offered in the hope that the young engineer might be encouraged to form the habit of reading widely. Recently the Committee extended its work further by making a survey of such educational facilities throughout the country as young engineers might find helpful in broadening their background. It also prepared a bibliography of engineering literature which forms a complement to the earlier reading list.

The functions of the Committees on Professional Recognition and on Professional Training are so closely related that it is very difficult to draw a sharp line of demarcation between the two. The particular province of the former, however, is the definition of prerequisites for admission to professional status. The Committee believes that if the minimum technical and intellectual background of engineers is to be improved, a certificate that is the equivalent of a professional degree should be the goal of attainment. It should be granted upon the successful completion of an examination and not be given as a mark of honor. The young engineer would probably be prepared to make application for it between his twenty-fifth and his thirtieth year. Its receipt should indicate that he is qualified for a state license or registration.

In accordance with these concepts the Committee made a tentative draft of a plan of certification. The Council has not yet adopted it, however, but has asked that it be given further study. In its initial form it advocated that all engineers now registered or licensed and those holding associate or full membership in the national societies be granted certificates upon request until January, 1937. After that date, certification should be on the basis of individual application only, but examinations might be waived in instances of obvious fitness. Beginning with January, 1938, all new applicants should be subject to both written and oral examinations, although theses, published papers, and so forth, might be accepted as the equivalent of the written portion of the test.[1]

The creation of the Engineers' Council has been looked upon as one of the most important efforts of recent years directed toward the professional advancement of engineering. The Council is still so young, however, that much of its work is necessarily in the preliminary stage. The task it has set for itself is extremely broad in scope and difficult of achievement. Nevertheless there is so earnest a desire to raise the status of engineering, and integrate and strengthen professional ties, that the Council is prepared to do its utmost to accomplish these aims.

NUMBER OF ENGINEERS AND DEMAND FOR THEIR SERVICES

The federal Bureau of the Census has reported some figures concerning the number of engineers at every decen-

[1] Engineers' Council for Professional Development: First Annual Report for Year Ending October, 1933; Second Annual Report for Year Ending October, 1934.

TABLE 3.—NUMBER OF ENGINEERS IN UNITED STATES AS SHOWN BY CENSUSES OF OCCUPATIONS, 1850 TO 1930[a]

Class	1850	1870	1880	1900	1910	1920	1930
Civil engineers and surveyors	2,126	7,374	8,261	26,017	52,033	64,660	102,086
Mining engineers	–	–	–	2,888	6,930[b]	6,695[b]	11,970[b]
Mechanical engineers	–	–	–	14,334	14,514[c]	37,689[c]	54,356[c]
Electrical engineers	–	–	–		15,278[d]	27,077	57,837
Total technical engineers and surveyors	2,126	7,374	8,261	43,239	88,755	136,121	226,249

[a] Figures are omitted in the table for 1860, for which year the census figure (27,449) evidently includes stationary and perhaps locomotive engineers, and for 1890 when technical engineers, surveyors, and electricians were combined in a single item.
[b] Includes chemical and metallurgical engineers.
[c] Includes engineers not elsewhere classified.
[d] Estimated in census report for 1920.

nial period since 1850. However, these figures are not as helpful as might be wished for measuring the growth of the profession, partly because the method of classification has been changed frequently. The Bureau has never been able to distinguish satisfactorily between engineers on the professional level and those of a lower grade. Surveyors, for instance, have not been differentiated from civil engineers except in 1870 and in 1900, when the Bureau reported 2,671 and 5,949, respectively. In 1880 surveyors do not appear either to have been included with civil engineers or to have been counted separately. Electricians were classified as engineers in 1890, the first census in which they represented a numerically important occupation, and in 1910 they were combined with electrical engineers. Until the beginning of the twentieth century, moreover, no attempt was made to classify engineers according to the several major branches of the profession, and even in the latest census they were distributed among only four categories. Another difficulty presents itself. There has always been a tendency for many persons to desire to be classified in an occupational category above that to which they could validly lay claim. How many members of related technical trades reported themselves to enumerators as engineers is unknown. It may be assumed, however, that a considerable number took advantage of the fact that the grades of engineering are not clear-cut and distinct, and hence registered their status in such a way that they were classified as professional engineers. These facts must be borne in mind in examining the figures in Table 3.

TABLE 4.—GEOGRAPHICAL DISTRIBUTION OF ENGINEERS HAVING MEMBERSHIP IN THE FOUR FOUNDER SOCIETIES IN 1934 OR 1935[a]

Geographical division	American Society of Civil Engineers 1935	American Institute of Electrical Engineers 1934	American Society of Mechanical Engineers 1934	American Institute of Mining and Metallurgical Engineers 1935	Total
New England	891	1,259	1,348	252	3,750
Middle Atlantic	4,352	5,983	5,176	1,706	17,217
East North Central	1,956	2,446	2,289	607	7,298
West North Central	1,061	700	490	261	2,512
South Atlantic	1,537	836	793	344	3,510
East South Central	464	203	186	106	959
West South Central	856	388	332	429	2,005
Mountain	646	313	161	721	1,841
Pacific	2,225	1,207	705	757	4,894
Total	13,988	13,335	11,480	5,183	43,986

[a] Members outside the United States not included.

If there were roughly 226,000 engineers and surveyors in 1930, they formed 0.46 per cent of the 48,830,000 gainfully employed persons. One engineer or surveyor was listed for every 543 persons and one for every 217 gainfully employed. Since engineering, however, is primarily an urban profession, we find the greatest concentration in those localities that are largely industrial. According to Table 4, which shows the distribution of some 44,000 engineers in the United States who hold membership in the four Founder Societies, the Middle Atlantic states with their high degree of industrialization and their relatively large population have over one-third of the total membership. The East North Central and the Pacific states are second and third in the number of engineers belonging to these national associations. The East South Central states, on the other hand, are primarily rural and they stand at the bottom of the list with a membership under 1,000. We may reasonably suppose that the distribution of the membership of these four societies is representative of the distribution of all engineers.

When examination is made of the census figures for 1930 which classify gainful workers by the industries to which they are attached, some interesting considerations emerge concerning the industrial distribution of engineers. The data are not accurate enough to permit too much reliance to be placed upon them, but they do point to certain valuable generalizations. Nearly 54,000, or about 24 per cent of all engineers, are classified under professional service. This large number comprises teachers of engineering

TABLE 5.—NUMBER OF ENGINEERS AND OF TOTAL WORKERS IN CENSUS INDUSTRY GROUPS CONTAINING MORE THAN 1,000 ENGINEERS, 1930[a]

Census industry group	Engineers	Total workers	Engineers as per cent of total workers in specified industry groups
Professional service, except recreation and amusement	53,641[b]	2,965,742	1.8
Public service not elsewhere classified	24,890	1,049,576	2.4
Building industry	16,490	2,574,968	.6
Construction and maintenance of roads, etc.	15,104	454,823	3.3
Telegraph and telephone	12,668	578,602	2.2
Electrical machinery and supply factories	12,526	383,570	3.3
Other iron and steel and machinery factories	12,476	1,213,548	1.0
Electric light and power plants	12,357	289,255	4.3
Steam railroads	10,431	1,583,067	.7
Automobile factories	4,537	640,474	.7
Blast furnaces and steel rolling mills	4,124	620,894	.7
Petroleum refineries	2,549	173,798	1.5
Other miscellaneous manufacturing industries	2,446	360,023	.7
Other chemical factories	2,406	179,880	1.3
Coal mines	2,355	691,288	.3
Other not specified manufacturing industries	2,276	465,559	.5
Insurance	1,821	507,299	.4
Oil and gas wells	1,751	198,446	.9
Not specified mines	1,615	31,219	5.2
Steel railroads	1,535	195,408	.8
Gas works	1,343	114,930	1.2
Water transportation	1,325	299,804	.4
Wholesale and retail trade	1,194	5,851,515	.02
Total, 23 census groups	201,860	21,423,688	.9

[a] Compiled from tabulation of gainful workers by industry and occupation. Fifteenth Census of the United States, vol. 5, chap. 7, pp. 403–587.

[b] In the opinion of several engineers consulted by the author, this number is considerably too large to represent engineers engaged in general consulting work and teachers of engineering. It is probable that a large number of the engineers included here should have been classified as attached to a particular industry, thus raising some of the subsequent figures.

and consulting engineers attached to no particular industry. Twenty-two other categories among the 127 industry groups listed by the census include 148,000, or 65 per cent of all engineers. This leaves only 24,000 engineers for the other 105 categories, to which are assigned more than 27,000,000 gainful workers.

Of the 23 industry groups presented in Table 5, several contain very high proportions of engineers. Thus in the miscellaneous mining category, 5.2 per cent of all workers are engineers; in electric light and power production, 4.3 per cent; in the manufacture of electric machinery, 3.3 per cent; in construction and maintenance of roads, 3.3 per cent; in public service as here classified, 2.4 per cent; in telephone and telegraph concerns, 2.2 per cent. In two small and relatively new industries shown separately in the census report the percentage of engineers is also high, 6.1 per cent in radio broadcasting and 2.6 in airplane transportation. In contrast to these high proportions, engineers are only 0.02 per cent of all workers in wholesale and retail trade, and in agriculture and many important branches of the other major industrial divisions practically no engineers are employed. If a demand for service is created in the future in the backward industries, as some engineers believe it inevitably will be, it will result in the need for many more engineers in the field of private enterprise. Engineering leaders assume that their profession has progressed to such a point that its methods and techniques can be of great value even to occupations seemingly remote from it. One writer states:

No one dares to set a boundary to the field of engineering twenty-five or fifty years hence. In fact, the only possible limits are those fixed by that degree of mastery of science which leads to economically predictable results. What men are asking is that engineers extend their methods to vastly wider fields. If engineering is good for manufacturing and mining, why not for farming and housekeeping? If it can cut production costs, why not the cost of distribution? If it solves the problem of fuel, why not that of food? The time is at hand to incorporate the biological sciences into engineering.[1]

Inaccurate as figures for the number of engineers may be, there is no doubt that the profession has grown with great rapidity. Unlike some of the other groups that showed definite signs of being overcrowded even before the economic depression began, engineering colleges were unable to meet the demand for graduates. Every discovery in the basic sciences or in the principles of engineering, every invention and development in engineering gave rise to still further discoveries, inventions, methods, and products. As a consequence, engineering and the demand for engineers grew at an ever-accelerated pace.[2]

The experience of the Employment Service operated jointly by the national engineering societies testifies further to the demand for engineers. In 1923 the Service actually placed more men than registered with it during the year. Registrations and placements ran along fairly uniformly until 1930. In that year, however, the depres-

[1] Wickenden, William E., "Training Engineers for Responsibility." In Professional Engineer, April, 1930, p. 7.

[2] Lucke, C. E., "Engineering." In Mechanical Engineering, November, 1926, p. 1089.

sion began to play havoc with employment, and, as a result, applications commenced to increase rapidly while placements fell off almost continuously for three years. In spite of the greatest vigilance on the part of the Service, local engineering organizations, and the American Engineering Council, which co-operated with the federal government in an effort to stabilize employment, it was impossible to stem the tide of adversity. A large part of all engineering work came to a complete standstill and the situation created thereby was very critical. The American Society of Civil Engineers estimated that at the end of 1933, of 100,000 civil engineers and surveyors, 45,000 to 50,000 were out of employment. Nearly 30,000 had been without work for at least a year, and 12,000 for two or more years.[1] The situation began to improve very slightly in 1933, showed further gain in 1934, and improvement has continued throughout 1935. Many engineers, however, have had to accept positions entirely outside the field of their training, and much of the still inadequate demand has been created by the initiation of government projects rather than by the activity of private industry. The experience of undertaking work of whatever nature they could find has been a very trying one for engineers. But it is not impossible that this experience will ultimately be viewed as a significant step in forcing them into even more diversified fields. From such diversification many believe that both the profession and society will eventually benefit.

The history of the last five years appears to indicate that

[1] Annual Report of the Board of Direction, 1933, p. 3.

engineers and architects are likely to be more at the mercy of economic variations than are the professions that offer their services in the main directly to individuals. Teaching, medicine, dentistry, social work, and the ministry are all so closely connected with human welfare that they have come to be somewhat removed from the operation of primary economic forces. Their contributions are now regarded as life necessities, and hence they have been elevated above the vicissitudes of business conditions. In spite of bitter hardships encountered by many of their members, they seem to weather economic depressions far better than do those professions that are primarily connected with the utilization of materials and natural resources. A period of financial strain finds the teacher much less affected than the engineer and the architect, who face industries in which construction and production have been cut to the core. A period of prosperity, on the other hand, sees the teacher the same plodding servant of the public good who does not win a substantial increase either in salary or in social esteem, while the engineer and the architect are everywhere in great demand and are given much more of an opportunity to gain distinction and earn reasonably large incomes.

SALARIES OF ENGINEERS

Information concerning salaries is more extensive and authoritative for engineers than for most of the other professional groups. Several studies have been made that have determined what men were earning at progressive levels of age and experience, and in different sections of the United States. Four of the most important of these studies will be reviewed briefly. The methods employed, the time, and the groups examined differ somewhat in each investigation. A comparison of the results of the four, however, furnishes a very adequate picture of salary trends.

Earnings of Graduates of Engineering Schools, 1924

The study made by the Society for the Promotion of Engineering Education[1] was based upon an analysis of earnings in June, 1924, of more than 5,000 men who had been graduated from representative engineering schools in all sections of the country in selected years prior to and including 1924. When the median beginning salary of $1,476 for graduates of 1924 was compared with the median beginning salary of $800 for graduates of 1914, it was found, even after allowance was made for the decreased purchasing power of the dollar in the later year, that the young engineer entering practice in 1924 was better off than was the graduate of the earlier period. The investigation revealed that the salaries of the older men had increased steadily but less rapidly than those of the recent graduates. When classified by years since graduation, as shown in Table 6, the maximum median salary was $7,500 and was earned by men thirty years out of college. Interestingly enough, the study did not show extreme differ-

[1] "A Study of Engineering Graduates and Non-Graduate Former Students." In Report of the Investigation of Engineering Education, vol. 1, pp. 234, 262.

TABLE 6.—ANNUAL EARNINGS IN 1924 OF ENGINEERS WHO WERE GRADUATES OF ENGINEERING SCHOOLS, BY YEARS SINCE GRADUATION

Year of graduation	Years since graduation	Number reporting	Annual earnings			
			Minimum	Median	Maximum	Most frequent
1924	0[a]	1,191	$ 300	$1,476[b]	$ 4,080	$1,200
1923	1	1,218	420	1,800	5,100	1,800
1922	2	1,023	360	2,100	9,000	1,800
1919	5	309	1,500	2,860	25,000	3,000
1914	10	498	1,200	4,000	50,000	5,000
1909	15	430	1,700	5,000	49,500	6,000
1904	20	238	1,920	5,500[b]	90,000	4,000
1894	30	116	1,980	7,500	100,000	6,000

[a] Beginning salary.
[b] Differs from corresponding figure in Table 1. The difference appears in the source tables.

ences in earnings of graduates of the many engineering colleges. What variations there were could easily be explained on the ground of diverse economic conditions in various parts of the United States.

Earnings of Graduates of Land Grant Colleges, 1928

In connection with its Survey of Land Grant Colleges and Universities in 1928, the United States Bureau of Education obtained over 37,000 replies to the questionnaire it sent to former students of the various schools in those institutions. From the data provided by the questionnaires, Donald S. Bridgman made a study for the Engineering Foundation of the earnings of the 31,000 men who filed replies. He not only prepared graphs showing the median earnings of graduates of land grant colleges at five-year intervals and the comparison of these earnings with the fluctuating cost of living, but he showed earnings by type of college training. It was at this point that his study became significant to engineers. When he compared the median earnings of men who had completed engineering, agricultural, or arts and science curricula, he found that engineering graduates were at a decided advantage over agricultural graduates. This was to be expected, as 60 per cent of the latter group were either in teaching or farming. Men with engineering training began with salaries of $1,500 or $1,600 a year, and their salary curve showed a steady upward trend. When they had been out of college slightly more than twenty years median earnings reached the $6,000 level. At thirty years after graduation, earnings were almost on the $7,000 level. Engineering graduates were at a disadvantage, however, as compared with arts and science graduates for nearly twenty years after completing college. The latter showed a much sharper gain in earnings during the early years, but after the fifteen-year point there was little further increase. Thus the older engineering graduates were able to go beyond the arts and science alumni in earnings.[1]

Median earnings were also determined according to the particular type of engineering curriculum in which men had majored as undergraduates. Civil engineering graduates received the highest initial salary, but their median earnings beyond twenty years after graduation were the lowest of four groups. Graduates in electrical engineering earned substantially less than the others at five and ten years after completing their college course, but at thirty years after graduation their median was the highest of all. It is probably true that the character of much civil engineering work is a handicap to steady progress in earnings, while in electrical engineering men begin at a low salary but many gain distinctive recognition in later years in those large organizations that employ great numbers of electrical engineering graduates. From fifteen to twenty-five years after graduation the median earnings of mechanical engineering graduates were larger than for those of civil or electrical engineers but less than those of the combined

[1] Bridgman, Donald S., "Earnings of Land Grant College Alumni and Former Students." In Journal of Engineering Education, November, 1931, pp. 175–197.

group of chemical, mining, architectural, and some other engineering graduates.[1]

Earnings of Mechanical Engineers, 1930

In September 1931, there appeared in the periodical Mechanical Engineering[2] a report by the Committee on the Economic Status of the Engineer entitled, "1930 Earnings of Mechanical Engineers." The salary data presented in this report were obtained from 9,199 mechanical engineers, not including teachers of engineering or engineers employed by the federal government. They related to professional earnings, not to total income. The depression had not seriously affected engineering salaries by 1930.

One of the surprising findings of this study was the extent to which earnings of exceptional men soared above those of men in the middle range. At ages fifty-eight to sixty-two years, the salary at the lower boundary of the highest 10 per cent of the group was 233 per cent higher than the median salary. Average earnings were so influenced by salaries in the high brackets that the arithmetic average for the age group fifty-three to fifty-seven, for which generally highest earnings were reported, was $10,200, while the median was $7,600. It was also found that salaries high in the salary scale continued to increase with years of experience much longer than those lower in the scale. Thus maximum earnings at the lower boundary

[1] *Idem,* "Engineering Graduates of Land Grant Colleges and Universities." In Journal of Engineering Education, June, 1932, pp. 863–864.

[2] Pp. 651–657.

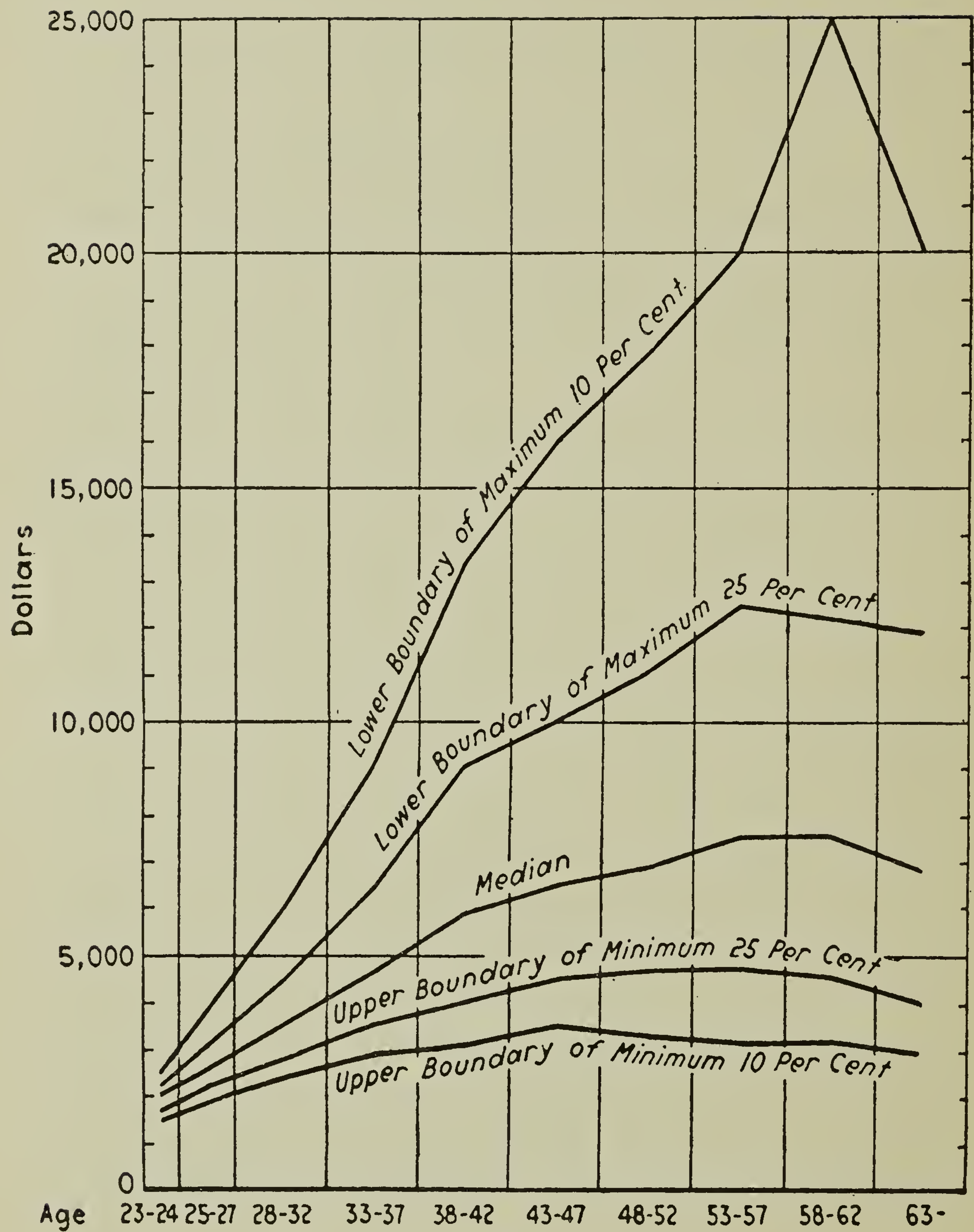

DIAGRAM I.—INFLUENCE OF AGE ON ANNUAL EARNINGS OF MECHANICAL ENGINEERS IN THE UNITED STATES IN 1930 of the top 10 per cent were not reached until age fifty-eight to sixty-two, but maximum earnings at the upper boundary of the lowest 10 per cent were reached as early as age forty-three to forty-seven. Median earnings were highest for the two age groups, fifty-three to fifty-seven and fifty-eight to sixty-two. The diagram opposite shows the relation of earnings to age as shown by this study and illustrates clearly the conclusion of the Committee that earnings of mechanical engineers do not decline seriously with age.

Table 7, which is based on the salary data plotted in the diagram, shows the rate of change with age of earnings at different positions in the salary scale. It indicates the periods of rapid and slow increase and of decline in salaries at different earning levels.

The report demonstrated that salaries varied not only with ability and age, but with geographic locality. The New York metropolitan district had the highest median earnings at all ages below sixty-three, but these were not substantially above earnings in the rest of the area of the Middle Atlantic states except for men over forty, or in the Middle West except for men over fifty. When the cost of living was taken into account, it was believed that there was probably little difference in favor of New York for men below fifty. How much of the sharp increase in earnings in New York City for men in their fifties was due to the calling of distinguished persons from other areas was impossible to determine. Median salaries were low in the South for all men above thirty-five. In the Prairie and in the Mountain and Pacific states earnings were distinctly lower than in other sections of the country.

An examination of the influence of education on earnings indicated that technically trained men from recognized engineering colleges earned about $500 more per year from twenty-five to thirty-five years of age than men with inferior training. After thirty-five they advanced more rapidly, and at forty-five they were more than $1,000 ahead of men with training of sub-collegiate rank or without technical training. After fifty-five, persons with graduate training earned less than men with standard engineering school training. This was possibly the result of the fact that the former tended to stay in strictly research positions and did not become general executives.

The study appeared to prove that, aside from teaching and railroad engineering, salary was little affected by the branch of engineering that one entered. If, however, a man could not combine with his technical skill a generous degree of capacity to deal with men and affairs, whether as a manager in an industrial organization or as a consulting engineer, his chances of earning a high salary were greatly reduced. Not only was he likely to fail to attain the highest positions, which were almost invariably those of a managerial nature, but after the age of twenty-five he generally found himself in the distinctly lower-paid types of work. Even in technical operation and especially the designing fields, the highest salaries were received by men whose work involved executive responsibilities.

TABLE 7.—RATE OF CHANGE IN EARNINGS WITH AGE INDICATED BY ANNUAL PROFESSIONAL EARNINGS OF MECHANICAL ENGINEERS IN 1930

Figures show indicated percentage of change per year of earnings at specified positions in the distribution of earnings at successive ages

Position in distribution of earnings	23½ to 26 years	26 to 30 years	30 to 35 years	35 to 40 years	40 to 45 years	45 to 50 years	50 to 55 years	55 to 60 years
Lower boundary of the highest 10 per cent	18.5	10.8	8.8	8.1	3.6	2.3	2.2	4.6
Lower boundary of the highest 25 per cent	14.7	9.2	7.2	7.4	2.1	1.9	2.5	−0.6
Median	12.1	7.5	6.0	4.7	1.7	1.2	1.9	−0.2
Upper boundary of the lowest 25 per cent	10.8	5.7	4.6	2.6	2.2	1.1	−0.2	−0.4
Upper boundary of the lowest 10 per cent	10.6	5.7	4.3	0.8	2.6	−0.9	−1.0	−0.1
	Period of rapid increase			Period of slow increase		Period of decline		

TABLE 8.—MEDIAN ANNUAL EARNINGS OF MECHANICAL ENGINEERS HOLDING MANAGERIAL AND NON-MANAGERIAL POSITIONS IN 1930, BY AGE

Age	In research and design			In technical operation		
	Managerial positions	Non-managerial positions	Ratio: managerial to non-managerial	Managerial positions	Non-managerial positions	Ratio: managerial to non-managerial
30 years	$3,600	$3,200	1.12	$3,600	$3,100	1.16
40 years	5,800	4,500	1.29	4,400	4,500	.98
50 years	6,700	5,000	1.34	6,100	5,400	1.13
60 years	5,700	3,900	1.46	5,600	4,800	1.16

Earnings of Engineers in Highway Departments, 1930 and 1934

The results of the preceding studies are so similar that it is safe to infer that they present a fairly accurate picture of earnings prior to 1930. They fail, however, to give one any idea of what has occurred to salaries in the past five years. It is for that reason particularly that recent surveys of the salaries of engineers and engineering assistants in the highway departments of 48 states are important. The

TABLE 9.—MEDIAN ANNUAL SALARIES OF ENGINEERS AND ENGINEERING ASSISTANTS IN HIGHWAY DEPARTMENTS OF 48 STATES, 1930 AND FIRST QUARTER OF 1934

Classification[a]	1930	First quarter 1934
1. Rodman, chainman, tracer, junior draftsman	$1,330	$1,200
2. Junior engineer, levelman, lower grades of draftsman and inspector	1,824	1,620
3. Higher grades of draftsman, transit man, engineering inspector, detailer, checker, squad boss, chief of party	2,280	2,000
4. Designer, designing engineer, special inspector	3,000	2,600
5. Engineer, resident engineer, section engineer	4,100	3,500
6. Division engineer, senior engineer, assistant chief engineer, or chief engineer of a minor organization	5,400	4,600
7. Chief engineer of a major organization	7,000	6,100

[a] Definitions of the duties, responsibilities, and educational requirements for each of the seven classes of positions will be found in "Revised Report on Salaries of Civil Engineers," Civil Engineering, August, 1934, pp. 424–425.

Committee on Salaries of the American Society of Civil Engineers obtained extensive information concerning these salaries in 1930 and again in 1933. Still later reports received from the local sections of the Society enabled the Committee to set down prevailing salary rates as of March, 1934.

From the data it received, the Committee was able, not only to work out the median salaries for the seven classes of positions that it listed, but to estimate the effect of geographic location and size of population upon salary. The following percentages indicate how much larger or smaller were salaries in various sections of the United States than were those for the entire country as given in Table 9:

New England	3 per cent more
Middle Atlantic	15 per cent more
East North Central	6 per cent more
West North Central	5 per cent less
South Atlantic	15 per cent less
East South Central	15 per cent less
West South Central	10 per cent less
Mountain	10 per cent less
Pacific	5 per cent more

Size of place had a decided influence upon salaries. Engineers employed in cities of 1,000,000 population earned about 10 per cent more than the prevailing salary scale for highway engineers in the particular region. In New York City salaries were approximately 30 per cent higher than those generally characteristic of the Middle Atlantic states.

An encouraging result of this study by the American Society of Civil Engineers is that its scale of prevailing salaries has been officially recognized as the standard for use in federal public work. Administrators had been greatly in need of some guide to salaries that was reliable and authoritative. If the government complies with this standard, the result should be highly beneficial to thousands of engineers in its employ whose earnings have been far below the median.[1]

Although the investigation of salaries among civil engineers has been of great value, it naturally did little to afford one any extensive knowledge of conditions in the entire engineering profession during the past few years. Because a detailed examination of unemployment, types of positions held, salaries, and so forth, in all branches of engineering seemed essential, the American Engineering Council has recently requested the Bureau of Labor Statistics of the United States Department of Labor to make such an examination. The study is now in progress and the results should provide a really comprehensive picture of the recent situation.

TRENDS IN ENGINEERING

The nineteenth century saw the average engineer a private practitioner. Not infrequently he was engaged in work that took him from Niagara Falls to the Rocky Mountains, if not to foreign countries. The twentieth century

[1] "Society's Prevailing Salary Scale Becomes Standard for Public Works." In Civil Engineering, April, 1935, p. 262.

sees him in 95 per cent of all cases, if one estimate is correct,[1] an employe of someone else. Decline in consulting practice, however, has been more than offset by the great gains that engineers have made in assuming industrial leadership. In spite of these gains, there have been much discussion and some regret among engineers concerning the rapid decrease in the amount of private practice in their field.

They point to the doctor, dentist, and lawyer as examples of professional men who are still independent, while their own group has steadily tended to become an employe class. They have sometimes failed to realize that even in those professions where private practice has maintained itself most persistently, men are less frequently hanging out their own shingle, and are more and more associating themselves with hospitals, clinics, departments of health, trust companies, corporations, and so on. Engineers have also neglected to take into consideration that it is not they, but the modern trend toward consolidation, that is responsible for the change. They have been forced to affiliate themselves with engineering firms or to become employes of business and industry. Regret as they may the passing of consulting engineers in private practice, they are unable to check the movement, for it is dependent upon tendencies that are becoming only more pronounced, and over which they have no control.

There are two chief objections that engineers raise to the

[1] Fraser, C., Story of Engineering in America. Thomas Y. Crowell Company, New York, 1928, p. 15.

loss of private practice: decrease in earnings and restriction of opportunity. When men enter the employ of a corporation they do so at a fixed salary, which is rarely equal to what the most able and the most fortunate might earn "on their own." The number of persons, however, who reach the high salary levels, even in private practice, are very few. The system of drawing men into industry has tended to iron out salary differences, and it is believed that as the process continues, uniformity of earnings will become more accentuated. While this works a hardship on those with exceptional ability, it has lessened some of the inequalities that always exist in private practice. A salary of $7,600 undoubtedly seemed small in 1930 to a mechanical engineer who had had thirty years' experience. Similarly $6,100 must appear meager to the civil engineer who assumes the vast responsibility of the position of chief engineer of a highway department. But when these sums are compared with the average salary or net income of other professional groups on similar levels of training and experience, it is fairly certain that the engineer comes off relatively well in the matter of financial remuneration.

In the opinion of many persons, the transition from private practice to employment in large and highly organized groups has forced engineers to sacrifice not only financial reward but opportunities of obtaining positions that demand all of their training and ability. This may frequently be true, but those who express this opinion seem to have overlooked how diversified engineering has become and how important a rôle engineers are playing in many types of work. There has been not only wide technical but functional diversification. At one end of the scale engineering merges imperceptibly into pure science, and at the other into business. Men are today engaged in design and research, maintenance and operation, construction, administration and supervision, sales, and engineering education. In all these fields great numbers of graduates of engineering colleges occupy positions vested with large responsibility. In business and industry they are being called upon increasingly to assume managerial duties. If business continues to shift from the small employer-owned form to the large corporate type, it must be operated more and more by trained salaried men. And as the technical aspects of methods of modern production become more important, the men who will be best fitted for executive positions will be the graduates of technical schools.[1]

A study made by the National Industrial Conference Board[2] a few years ago clearly indicated the trend in the growth of technical and administrative leadership. The Board estimated that in 1920, 1,510,000 persons, or 3.6 per cent of all gainfully employed, planned the activities and directed the energies of the working force of 42,000,000. The country had seen a tremendous transition between 1870, when there were supposedly only about 170,000 administrators, and 1920 when the number was probably in excess of a million and a half. Even more

[1] Lewisohn, Sam A., The New Leadership in Industry. E. P. Dutton and Company, 1926, New York, p. 87.

[2] Engineering Education and American Industry, Special Report no. 25, New York, 1923, pp. 1–14.

significant, however, than the growth in the number of the managerial and planning class, had been the increase in the percentage of this group as compared with the increase in the percentage in the total number of gainfully occupied. Between 1870 and 1920 the proportion of administrators and technical experts grew from 1.25 to 3.6 per cent of all gainfully occupied workers, while during the same period workers increased from 32.4 to 39.4 per cent of the entire population. The period of greatest increase in demand for administrators, supervisors, and technical experts apparently came between 1890 and 1910. Since then the rate of expansion has been slower but continuous. Indications seem to point to a demand which will go on increasing, probably less rapidly than at the beginning of the century but fairly steadily for some time to come. The development of corporations, the increasing use of machinery, power, and other labor-saving devices, and the elaboration of methods of control in production and distribution all make necessary an ever larger proportion of men engaged in planning and administration.

In such planning and administration, therefore, seems to lie the future opportunity of the engineer. He will rarely be a free agent who can engage in private practice where and when he wishes, but he will find in a profession as widely diversified as engineering, if the economic order is fairly stable, work that affords occasion for growth and development. The extravagant prophecies that were once heard of limitless possibilities may not and probably will not be fulfilled, but engineering appears capable of offering an interesting, productive, and relatively remunerative career to an increasingly large number of men. In these respects, it is more fortunate than some of the other professions.

Erratum

For the sentence beginning at the bottom of page 51 the two following sentences should be substituted:

> The National Bureau of Engineering Registration was established by the Council primarily to serve as an unofficial agency, in order to facilitate interstate registration of professional engineers. Possession of a certificate of qualification conferred by the Bureau does not take the place of registration in any state, but the certificates may be accepted by state boards in lieu of further examination.