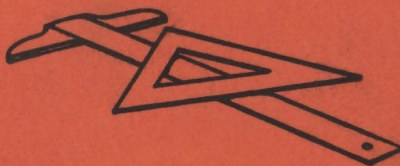
CAREERS IN

Engineering

Requirements • Opportunities



LOWELL O. STEWART

THIRD EDITION

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Engineering

Requirements • Opportunities

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Introduction

THE principal objective of this booklet is to furnish information about engineering to young men (and their parents) who are planning their careers. It does not provide answers, except incidentally, for the general problem of choosing a vocation or career.

Three standard questions are: What does one do? What abilities and interests should one have? What are the opportunities for building a successful, happy, and useful career? We will discuss in some detail the questions that refer to abilities, interests, and qualifications.

The reader of this booklet will be seeking to know: What will be the opportunities in a *specific branch* or field of engineering? What will be the opportunities in the *broad area* where any type of engineering may be needed?

This has become an engineer's world. Each year industries that have not employed engineers find that they have need for men with engineering training. There are increased demands for engineering graduates from the well-established fields of employment. Many companies are seeking managers and executives from their engineers who have shown the necessary qualifications. The rapidly expanding knowledge of the scientist in the field of nuclear fission will increase the call for high-level engineering, because it is the engineer who must translate these principles into useful and workable practice. These factors are operating to increase the number and the caliber of engineers that will be needed. Forecasters who based their estimates of the number of engineers needed on a previous ratio of X engineers per thousand population now find that they must use a larger value of X.

During the years since World War II the number of positions available in all fields of engineering has kept pace with the number of graduates. For example, the number of engineering graduates with the B.S. degree was nearly fifty thousand for the year 1949–50. The number dropped to about twenty thousand in 1953–54. In spite of pessimistic predictions about an oversupply of engineers, all of these graduates were able to find satisfactory jobs.

It is true that many of the fields of engineering pass through cycles that range from intense activity to semi-dormancy. To a certain extent this cycle of change affects the employment of engineers whose education, experience, and major ability is in that field. Naturally, the impact of this increase or decrease in demand for engineers is felt most severely by those who work in the more specialized branches of engineering. Generally, new processes or new discoveries, or revival or change in demand for products or materials, will prevent a field of engineering from vanishing.

Certain trends in engineering education may operate to limit and, to some extent, stabilize the enrollment of our engineering colleges. These trends are: (1) Gradual raising of the scholastic requirements for entrance and for graduation. This would call for more adequate high school preparation and a higher selectivity by the engineering college from among the high school graduates. (2) Extending the curriculum to more than four years, which also is in line with the trend in other professions. The hoped-for effect of these two steps would be to restrict graduation from the engineering colleges to a presumably better qualified group of men. This limitation would, in turn, provide professional engineers who would give a higher type of engineering service to the public and to employers. As a result, engineering as a profession would grow in the public's esteem; recognition, standards, working conditions, and salaries of engineers would rise.

Another trend that will have an effect on engineering education is the growing interest in general education. Many laymen, teachers, and engineers claim that the typical engineering graduate fails to play his full and expected role as a citizen and as an engineer because, they say, he does not know about and understand the areas of education that are covered, broadly, by the social sciences and the humanities. Engineering educators have sought for many years to correct this alleged deficiency of engineers by integrating a group of social-humanistic courses into the engineering curriculum. By 1955 the recommended optimum percentage of this type of courses was 20 per cent of the curriculum.

Experience has shown that significant changes in the engineering employment picture may take place during the four years of a typical college curriculum that leads to the B.S. in Engineering. There are times when the number of jobs available at graduation in a specific engineering field may be larger or smaller than the number of students who will receive B.S. degrees. One of the reasons for this is that young men eager for an engineering education will strive to enroll in what they think, or have been told, is a fast-growing or expanding field where there will be good positions and attractive salaries on graduation day.

Actually, a man should not base the choice of his curriculum on such reasoning. Instead, he should choose the field for which he is fitted by aptitude and interest, assuming that these have been adequately ascertained and correctly measured. He should look into the future as far and as keenly as he can.

Interest in graduate work, leading to a master's degree or a doctor of philosophy degree in Engineering gained impetus after World War II. There is an increasing number of attractive employment opportunities for those who earn advanced degrees. Men who choose to go beyond the bachelor's degree to these advanced degrees will need particularly good education in mathematics, the physical sciences, the basic engineering sciences, and the advanced courses of their chosen field of specialization.

I hope that the young man who is considering a career in engineering will gain a clear understanding of the work of the engineer, the technician, and the craftsman. Each of these three fields offers enjoyable work, a good income, and opportunities for service and for advancement. Each is important and necessary for the successful completion of most engineering construction and manufacturing enterprises.

A man who serves well as a craftsman, as a technician, or as an engineer is doing his life's work successfully. A man's happiness, as well as the public good, demands that he find his life's work in occupations that fit his aptitudes and interests. It is a mistake to try to make a misfit engineer out of a man who could have been a successful steam shovel operator. Furthermore, it costs at least $4,000, plus the earning time lost, to obtain the bachelor of science degree in engineering. A technician can complete his formal education in half that time or less. A craftsman learns as he works at his apprenticeship.

The opportunities in engineering for men who have the aptitude, interest, and industry are attractive, challenging, and numerous. As the work of the engineer eases the burdens and increases the comforts and leisure time of people, the greater the demands become.

chapter 1

What Is Engineering?

THE activity that we call Engineering began as an art and a craft thousands of years before man had adequate devices for the keeping of records. From pictures and ruins of those times we can see that there must have been men who were skilled in planning and building, and who were recognized and respected because of their special skill and ability. They planned and directed the building of huge projects such as the Egyptian pyramids, the irrigation canals of Mesopotamia, and the temples of the Mayans in Central America.

These men were not known in their time as engineers; that word was to come later. In ancient Egypt they were called "superintendents"; Archimedes was a "wise man" of Carthage; Vitruvius, a Roman of the first century before Christ, was called "architect," this word coming from the Greek and meaning chief builder.

Also during this period, another group of men was carrying on similar activities in the armies. They built fortresses for defense and implements for offense, and canals, roads, bridges, breakwaters. In most instances these projects were built for military purposes. Probably Cyrus had such men about 500 B.C. when he diverted the Euphrates River and took Babylon; doubtless, Julius Caesar had such expert help when he bridged the Rhine; and Louis XIV had the advice of Vauban during the latter half of the seventeenth century.

Derivation of Engineer. Men who performed those kinds of tasks were called "engineers" in Italy and France seven or eight hundred years ago because they were *ingenious* and conceived things out of their heads. Much later came the development of machines called engines, and men who operate them are called engineers, also. This double use of the word has caused misunderstanding and confusion for those who are interested in the profession of Engineering. Probably the words engine and engineer sprang from a common root. But engineer in the professional sense did not grow out of engine. Engineer derived from engine would mean one who operates an engine. Recently the word engineman has been used to designate an engine operator. The form of the word for engineer in some of the European languages means "ingenious designer." Clearly, those who first took the name engineer to describe their work were designers and creators, not machine or engine operators.

During the seventeenth and eighteenth centuries there were increasing developments in science. As information became available the abler architects and craftsmen began to apply the principles to their daily work. They used mathematics as a tool in their practical calculations and to push farther into the unknown. They began to understand and use the laws of chemistry and physics. And out of their theoretical and experimental investigations there gradually evolved a substantial body of principles. Henceforth, engineering was a triad of art, craft, and science, with science holding the increasingly dominant role.

It is a matter of interest to know when the work of these builders began to have public recognition. Usually names follow practices. Their work came to be known as military engineering and civil engineering, the former relating to operations of war, the latter to works for civilian use and called civil to distinguish them from military. We know that John Smeaton, an Englishman, was the first man to call himself a "civil engineer." That was in 1761. He was the designer and builder of the great Eddystone lighthouse. His report on that structure contained the phrase, "my profession of a civil engineer." There have been many developments and many kinds of engineering since the days of John Smeaton. We will discuss these later.

Definition of Engineering. At this point we are ready to define engineering and to see how it measures up to the requirements of a profession. Most definitions have their source in that famous contribution to engineering terminology which was made by Thomas Tredgold in the early 1800's for the charter of the Institution of Civil Engineering in Great Britain. He called engineering "the art of directing the great sources of power in nature for the use and convenience of man."

Many definitions of engineering have been written, as the field has grown since the days of Tredgold. In the main, these later definitions emphasize science and materials and give increasing attention to the place of engineering in the management and human relationship fields. For example, "Engineering is the art of applying the laws of the natural sciences, including mechanics and thermodynamics, to the utilization of the materials and forces of nature in producing facilities for the benefit of mankind, and the art of organizing the human effort required in connection therewith."[1]

Also, the responsibilities of the engineer include "the entire range of technical and executive direction involved in the production of fuels and industrial materials, the planning and erection of structures, the design and fabrication of industrial products, the planning and operation of utility services, the ordering of industrial plants and processes, the sale of technical products and their adaptation to special uses, and the administration of technical enterprises, both private and public."[2]

Time and Engineering March On. In 1955 the Committee on Evaluation of Engineering Education of the American Society for Engineering Education, in discussing the objectives of engineering education and the pattern that it should take in the future, stated, "The pattern . . . must, of necessity, be based upon the obligations of the engineering profession to Society and upon the importance of the development of the student as an individual. The obligations of an engineer as a servant of society involve the continual maintenance and improvement of man's material environment, within economic bounds, and the substitution of labor-saving devices for human effort.

"The first objective, the technical goal of engineering education, is preparation for the performance of the functions of analysis and creative design, or of the functions of construction, production, or operation where a full knowledge of the analysis and design of the structure, machine, or process is essential. It also involves mastery of the fundamental scientific principles associated with any branch of engineering . . .

"The second objective, the broad social goal of engineering education, includes the development of leadership, the inculcation of a deep sense of professional ethics and the general education of the individual. These broad objectives include an understanding

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[1] Preliminary draft of report on Civil Engineering Curricula by Committee on Education, A.S.C.E., T. R. Agg, Ames, Iowa, July 17, 1940.

[2] Report on Aims and Scope of Engineering Curricula, *Journal of Engineering Education,* Vol. 30, March, 1940, p. 558.

of the evolution of society and of the impact of technology on it; an acquaintance with and appreciation of the heritage of other cultural fields; and the development of both a personal philosophy which will insure satisfaction in the pursuit of a productive life and a sense of moral and ethical values consistent with the career of a professional engineer."

In discussing the attainment of these objectives by the elimination of material now in the curricula and the addition of new curricula, the committee recommended, "Other areas due for close scrutiny, with a view toward possible elimination or reduction in time, are those courses having a high vocational or skill content and those primarily attempting to convey engineering art or practice. Some attention to engineering art and practice is necessary, but their high purpose is to illuminate the engineering science, analysis, or design, rather than to teach the art as engineering methodology.

"A review of the evolution of engineering curricula over many years shows a trend toward increasing emphasis on the science underlying engineering at the expenses of the study of engineering art for its own usefulness."[3]

CHARACTERISTICS OF A PROFESSION

In the foregoing paragraphs we have given a good deal of attention to the objectives of engineering education, because objectives or goals are of first importance in determining what will be the outcome of the educational process. We have used the word "profession" several times. It has both a broad and a narrow or restricted meaning and use. In its general use it means the occupation or calling to which a man devotes himself. When used in that sense, a man's work could be termed his profession—excepting, perhaps, trades, commercial and agricultural pursuits, and the like.

We are interested here in the restricted meaning of profession. It is necessary that we see the implications of the attitudes and points of view, expressed and implied, in the following definition if we are to have a real understanding of "engineering" and the work of the engineer. Many years ago the late William E. Wickenden composed this good definition of a profession:

In its higher senses, a profession is an occupation which:

1. Renders a specialized service, based upon advanced specialized knowledge and skill, and dealing with its problems primarily on an intellectual plane rather than on a physical or a manual-labor plane;
2. Involves a confidential relationship, between a practitioner and a client or employer;

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[3] Report on Evaluation of Engineering Education, American Society for Engineering Education, June 15, 1955, p. 19.

3. Is charged with a substantial degree of public obligation, by virtue of its possession of specialized knowledge;
4. Enjoys a common heritage of knowledge, skill, and status to the cumulative store of which professional men are bound to contribute through their individual and collective efforts;
5. Performs its service to a substantial degree in the general public interest, receiving its compensation through limited fees rather than through direct profit from improvements in goods, services, or knowledge which it accomplishes;
6. Is bound by a distinctive ethical code, in its relationships with clients, colleagues, and the public.[4]

The description or definition of a "professional man" is given from another point of view in the section of the Taft-Hartley Act of the 80th Congress, which deals with collective bargaining. According to this act, a "professional employee" means any employee engaged in work (1) predominantly intellectual and varied in character as opposed to routine mental, manual, mechanical or physical work; (2) involving the consistent exercise of discretion and judgment in its performance; (3) of such a character that the output produced or the result accomplished cannot be standardized in relation to a given period of time; (4) requiring knowledge of an advanced type in a field of science or learning customarily acquired by a prolonged course of specialized intellectual instruction and study in an institution of higher learning . . . as distinguished from a general academic education, or from an apprenticeship, or from training in the performance of routine mental, manual, or physical processes.[5]

GROUPS THAT MAKE THE ENGINEERING FRATERNITY

Although Engineering is a profession, as we have defined it in the preceding paragraphs, the activities of those who call themselves Engineers are so numerous and so varied that we find it difficult to classify all of them in one reasonably homogeneous group. This fact is the root of many discussions on which courses should be included in an engineering curriculum. Some people would include many courses in various areas, such as administration, management, construction, selling, because many graduates of engineering colleges find careers in those fields.

Actually, the practice of those who call themselves engineers may include, in varying amounts, some aspects of a trade, a business, and a profession. Included among these engineers are men whose abilities, education, and training extend from that of the

[4] *A Professional Guide for Junior Engineers,* William E. Wickenden, p. 32, Engineers' Council for Professional Development, New York, 1949.
[5] Taft-Hartley Act, Section 2 (12), 80th Congress.

most advanced scientific and technical type to that of the practical "school of experience" type. Because of this broad and heterogeneous mixture of abilities we might, with some justification, designate this group the "engineering fraternity," expecting that those with the aptitude, interest, industry, and personality will rise to meet the requirements of a profession.

Engineering enterprises require the services of three groups: skilled artisans, technicians, and professional engineers. There are no strict boundary lines—legal, technical, educational, or traditional—that mark off each group. They merge into one another, and many men are continuously in the process, by education and experience, of raising themselves from a lower to a higher level. Each of the groups does have certain essential and distinguishing traits which we shall now discuss in some detail, beginning with the artisan or craftsman.

Skilled Artisans or Craftsmen

This group contains nearly 30 per cent of the entire population of gainful workers in the United States. It is larger than any of the other groups, such as unskilled manual laborers, semiskilled factory operators, skilled clerical workers, and the professions. Because of the large numbers involved and the length of time devoted to training and experience, either through formal schooling or apprenticeship, this group, known as the *skilled trades,* has a great deal of economic and educational importance.

Skilled Trades are manual occupations for which more than two years of special training are ordinarily prerequisite. This training may be gained through course work in trade and vocational schools, technical high schools, or apprenticeship. Examples of skilled trades are patternmaker, sheet-metal worker, machinist, toolmaker, blacksmith, molder, electrician, carpenter, mason, painter, compositer, pressman, weaver, watchmaker, and many others. Several of these have subgroups, each of which is more or less a specialty.

For example, there are many kinds of machinists. Using the strict meaning of the word, machinists are people who machine metal, that is, cut metal. Some machinists make machines, others erect them or operate them. Detailed classification would include under the general heading of machinist such workers as: operators of punch presses, drill presses, shapers, broachers, boring mills, and grinders; millwrights, who erect machinery; and tool and diemakers, known as the aristocrats among machinists.

Inasmuch as these skilled artisans and craftsmen are so numerous and are so intimately and indispensably linked with the details of manufacturing processes, it follows that the way of the skilled trades is a good route to success and positions of responsibility. Many of our captains of industry and their principal subordinates have come up through the ranks of craftsmen. All large industries are keenly alive to the importance of having an alert and efficient group of skilled workmen. Some companies maintain well-organized and competently supervised apprentice training courses; others cooperate with public and semipublic groups that are carrying on vocational education programs.

Traits of Successful Craftsmen. There is a widespread general belief that *manual dexterity* is the only prerequisite for success in a trade. Probably the common classification of manual occupations—unskilled, semiskilled, and skilled—which seems to place the emphasis on degrees of manual skill, has fostered that belief. Actually, the success of a skilled craftsman is also dependent upon his *technical knowledge* and the *sound judgment* which he exercises when he makes decisions. Comprehensive and extensive groups of intelligence tests show that successful skilled craftsmen rank *above the general average in intelligence* and that the best of these are near the professions at the top of the intelligence rating scale.

This observation on the significance of better-than-average intelligence should be noted by those who think that learning a trade offers a successful way out for men who make unsatisfactory scholastic records in the engineering college. Their lack of ability to master academic subjects may include lack of mechanical aptitude also. Each case should be examined. The answer should be based upon a comparison between the individual's aptitudes and interests and the requirements of the craft considered.

We shall enumerate, in the order of their importance, the traits possessed by successful skilled craftsmen: (1) better-than-average intelligence, as measured by a standard intelligence test; (2) definite interest in learning the trade and progressing in it; (3) ability to acquire manual expertness in the required skills. The extent of this ability may be ascertained by standardized and established tests or by work in the shop under actual operating conditions. There should be concrete evidence of one's ability to acquire trade knowledge and exercise practical judgment as well as to become proficient in the use of the working tools of the trade chosen. No one will find pleasure in a trade that is hard for him to learn, nor will he get far in the apprenticeship if he is clumsy and dull.

Engineering Technicians

Engineering technicians occupy the area and perform functions between the artisans and the professionally prepared engineer.

Some of their jobs are quite elementary and routine; others require a high order of detailed technical ability. Most engineering graduates serve a short training or "experience-gaining" assignment to such tasks. Here they learn the important methods of their company and at the same time are under observation by the responsible officials. This is the beginning of the young man's climb toward a position where he can rate as an engineer. Some graduates never rise above the level of routine performers and, although engineering graduates, do not become engineers.

Work of the engineering technician includes surveying, drafting, inspecting, testing, laboratory analysis, time keeping, cost keeping, time and motion study, servicing and selling, and others. Obviously, these jobs are so closely related to the important work of industry that it would be difficult to draw a line separating technicians from engineers. There is a wide common band or twilight zone in which both technicians and young men headed for engineering are employed. Some stay in this area by choice; others, because of aptitude, interests, or limiting factors, find it necessary to remain. This need not be taken as a sign of failure. Many important jobs are found in this area and there must be men to do the work.

There is a large number of such positions. Our present system of technical education in the United States does not make sufficient provision for the selection and training of men to fill them. There are several schools, generally designated Technical Institutes, that offer terminal programs about two years in length for the training of technicians. Recently, the Engineers' Council for Professional Development recognized the importance of these schools and set up machinery for their evaluation and accreditation as technical institutes.

Many technicians come from the ranks of the four-year engineering college graduates or from the group that did not complete requirements for the B. S. degree. Others move out of the ranks of craftsman and trade school or technical high school graduates. Some receive specific training through organized programs maintained by companies that have a need for people with specific skills. For the majority of these technician positions the pay is below that of a craftsman, and subtantially above that of a common laborer.

Need for Technicians. If the estimates of employers who need technicians are correct there is a large annual unfilled demand for such men. The solution offered in several industrial centers is short, practical, and intensive courses of study lasting about two years that are designed to prepare men for immediate assimilation into an industrial organization. This plan has two advantages. For the employer it provides men with specific training who can work effectively from the start; for the employee it provides a short, intensive, not-too-expensive training which is leading toward a definite job.

There are disadvantages, too, but they can be minimized or eliminated. At the present time many young men are entering curriculums leading to the B. S. in Engineering who should follow a shorter, more practical program. This desire to earn the B. S. in Engineering is natural because of the eternal ambition of young people to get ahead, and because few are willing to admit that their abilities do not warrant the investment in a regular four-year engineering curriculum. Therein lies one of the knotty problems of our American educational program. Sufficient progress has been made with prognostic tests to warrant the hope that we shall soon be able to offer sound educational advice to young men on the likelihood of success in various college curriculums, as well as to offer alternate suggestions in case the outlook for success in college seems doubtful. We must also develop a technique which will enable us to persuade them to follow the advice. Everyone cannot "become president."

The Professional Engineer

Now we face the question, When and how does an engineering graduate become a professional engineer? Certainly not upon graduation from the engineering college. Probably not after any specified number of years of experience. During this experience-gaining period he has advanced beyond the engineering technician. He has shown considerable ability in the application of the fundamental principles of science and engineering to the solution of problems. These problems may be highly technical, requiring research or ingenious and complex analyses and designs; then again, they may call for demonstrated, creative ability in technical fields, or in administration, management, organization, or economy. Probably a ruling requirement will be that the engineering graduate has demonstrated the ability to have responsible charge of an engineering project of some importance.

As we have noted earlier, men with degrees in engineering, and who rate themselves engineers, are engaged in a variety of activities that call for varying amounts of engineering ability. Because of this confusion and because there is increasing need for a standard mark for those who are engineers, there is a growing movement to have all engineers become registered professional engineers.

Engineering Registration, or the licensing of an individual to practice professional engineering, is a legal requirement of each of the states and territories of the United States and of many foreign countries. The legal basis for this registration or licensing of individuals to practice engineering rests upon the fact that the practice of engineering, in cases such as the design and construction of structures, waterworks, heating and ventilating systems, electrical systems, and boilers affects the life, health, property, and public welfare of the citizens. Therefore, the state seeks to safeguard the life, health, and property, and to promote the general welfare by restricting the practice of professional engineering to those who are able to satisfy the requirements of the state's board of engineering examiners.

The engineering registration laws of many states follow the pattern of the Model Law for the Registration of Professional Engineers and Land Surveyors.[6] This model law represents more than a quarter of a century of work by the principal engineering societies of the United States.

It defines a professional engineer as "a person, who, by reason of his specialized knowledge of the mathematical and physical sciences and the principles and methods of engineering analysis and design, acquired by professional education and practical experience is qualified to practice engineering as hereinafter defined, as attested by his legal registration as a Professional Engineer."

This model law defines Practice of Engineering as "any professional service or creative work requiring engineering education, training, and experience and the application of special knowledge of the mathematical, physical, and engineering sciences to such professional services or creative work as consultation, investigation, evaluation, planning, design, and supervision of construction for the purpose of assuring compliance with specifications and design, in connection with any public or private utilities, structures, buildings, machines, equipment, processes, works, or projects."

General Requirements for Registration. All states have standards of qualification which they consider "minimum evidence satisfactory to the Board that the applicant is qualified for registration as a Professional Engineer. . . ." These requirements are oftentimes set up to cover three types of applicants, as follows: (1) those who qualify on graduation plus experience, (2) those on experience plus examination, and (3) those engineers of long-established practice. The specification of the model law on those who qualify by graduation plus experience will illustrate the nature of the require-

[6] The Model Laws for the Registration of Professional Engineers and Land Surveyors, National Council State Boards of Engineering Examiners, Charleston, S. C.

ment. It is: "Graduation in an approved engineering curriculum of four years or more from a school or college approved by the Board as of satisfactory standing; and a specific record of an additional four years or more of experience in engineering work of a character satisfactory to the Board, and indicating that the applicant is competent to practice engineering (in counting years of experience, the Board at its discretion may give credit, not in excess of one year, for satisfactory graduate study in engineering), provided that in a case where the evidence presented in the application does not appear to the Board conclusive nor warranting the issuing of a certificate of registration, the applicant may be required to present further evidence for the consideration of the Board, and may also be required to pass an oral or written examination, or both, as the Board may determine. . . ."

Examinations. The standard pattern of written examinations is two eight-hour examinations. The first day's questions cover the fundamentals, which is usually an examination over the principles in the courses of the engineering curriculum. The second day's questions cover the work of the applicant's field of practice and are designed to prove his competence to practice, as defined by the law.

The final rating of the applicant is usually made by giving weight to his examinations and experience. The following from rules of the Iowa Board are illustrative: "The final rating of an applicant shall be determined by the following: Personality, having to do with character, evidence of a general engineering interest and executive ability equals 10 per cent of total rating. Experience (nature and extent) equals 15 per cent of total rating. Written examination in fundamentals equals 35 per cent of total rating. (Oral examination in fundamentals equals 30 per cent, and 20 per cent on engineering experience, personality, character and executive ability when oral examination is taken.) Examination in principles of good practice, consisting of a certain number of questions in writing, depending on the branch of engineering taken equals 40 per cent of total rating with written fundamental examination and 50 per cent of total rating when oral fundamental examination is given. The candidate must make a grade of at least 60 per cent on this portion of the examination. A final rating of 70 per cent shall be considered a passing grade."[7]

As mentioned in an earlier paragraph, many engineers who are competent and qualified have not chosen to become registered professional engineers. In 1955 there were approximately 200,000 registered professional engineers in the United States which is, prob-

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[7] 1954 Report, Iowa Board of Engineering Examiners.

ably, less than 50 per cent of those who are qualified for registration. There is no compulsion to become registered on those who are not designing and building works for public or private interests not their own (or are employers of corporations so engaged). Federal and state employees and practically all of the engineers who work for industrial corporations are not required by law to seek registration. However, the trend toward registration, whether called for by law or not, as the mark of a professional engineer is growing, and the time is near when every man who calls himself an engineer will be a registered professional engineer.

Many state boards of engineering examiners provide for a grade designated Engineer in Training. Under this designation an engineering student may take the fundamentals portion of the registration examination during the final quarter or semester of his senior year in college, deferring the final portion of the examination until he has acquired the necessary qualifying experience. It is hoped that many seniors may be persuaded to take this Engineer in Training examination, and that they will follow with completion of the requirements for registration. If this happens, the number of registered professional engineers will show a marked increase and the professional status of engineering will be strengthened.

THE ENGINEERING SOCIETIES

Engineers who are engaged in related activities have found it desirable and advantageous to band together to form organizations commonly designated "societies." Here they are able, through technical meetings, research, and various types of publications, to keep informed about developments in their fields. Also, through the efforts of the societies, they have maintained contacts with legislatures and public agencies, with the public press, and with other organizations.

These societies are international, national, statewide, and local in their activities. One of their significant characteristics is that they operate independently of one another, with only loose bonds of cooperation. Four of these, known as the Founder Societies, were established before 1900. They have headquarters and offices at 29-33 West 39th Street, New York City, in a large building which they own jointly. This building was becoming too small in 1955, and there was discussion about a new one. The four founder societies are American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, and American Institute of Electrical Engineers.

There have been numerous attempts to "unify" the engineering profession. One of these is represented by the National Society of Professional Engineers. Since its establishment in 1934, this society has tried to reach a position in membership and prestige where it can speak with authority for the entire engineering profession. Its principal emphasis is upon the professional, social, and economic status of engineers with little attention to technical matters.

Acting on this unification idea from another angle is the Engineers' Council for Professional Development (ECPD) which is "a conference organized to enhance the professional status of the engineer through the cooperative efforts of the following national organizations, concerned with the professional, technical, educational, and legislative phases of engineers' lives: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, The Engineering Institute of Canada, American Society for Engineering Education, American Institute of Chemical Engineers, National Council of State Boards of Engineering Examiners."

The ECPD does many useful things for the engineering profession in areas such as student guidance, accrediting engineering curriculums, professional education, training and recognition, engineering ethics, and the dissemination of information about them.

However, it does not have the organic structure that enables and qualifies it to speak for all engineers. So, we have an organization named Engineers Joint Council (EJC), a federation of several national engineering societies, that is trying to bring all engineers into one federated group. Constituent societies of this federation in 1955 were: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Waterworks Association, American Institute of Electrical Engineers, Society of Naval Architects and Marine Engineers, American Society for Engineering Education, American Institute of Electrical Engineers.

The parent of these technical societies is the Institution of Civil Engineers founded in 1818 in England. The American Society of Civil Engineers was founded in 1852.

The development of the steam engine and other mechanical devices brought together a large number of men with a common interest in things mechanical. Quite naturally, this group separated from the parent group of civil engineers to form a distinct profession, Mechanical Engineering. In England, the Institution of

Mechanical Engineers was founded in 1847, and George Stephenson, the locomotive builder, was its first president. The American Society of Mechanical Engineers was founded in 1880.

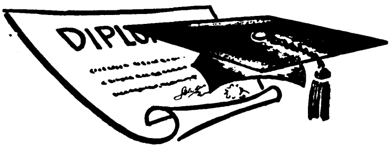
Men interested in mining engineering decided to set up their own profession in the eighties also. So we find the Institution of Mining Engineers founded in England in 1889 and the American Institute of Mining Engineers in 1871. The latter is now known as the American Institute of Mining and Metallurgical Engineers.

The next group to form a society was the Electrical Engineers. The Institution of Electrical Engineers was founded in England in 1883 and the American Institute of Electrical Engineers in 1884.

A long period elapsed before another division occurred. In 1908 men interested in chemical manufacturing and related problems, which were different from the purely chemical aspects, called themselves Chemical Engineers and founded the American Institute of Chemical Engineers.

Men interested in the application of power to the farm called themselves Agricultural Engineers and founded the American Society of Agricultural Engineers in 1916.

Many other engineering societies have been formed. Some of these will be mentioned later in connection with the degree-granting departments. In general, the numerous technical societies (there are about 300) represent very special technical fields. Examples of these societies are: American Railway Engineering Association, American Society of Heating and Ventilating Engineers, American Society of Safety Engineers, American Society for Testing Materials, American Concrete Institute, Institute of Radio Engineers, Illuminating Engineering Society, Society of American Military Engineers, Society of Automotive Engineers, and others. Also, there are many state, city, and local engineering societies and clubs, whose field of operation seems to be a combination of the technical, economic, and legislative. Besides these, there are many kinds of engineers who operate as a division of the parent society. In this group are highway engineers, structural engineers, sanitary engineers, transmission engineers, electronic engineers, communication engineers, and others. These numerous specialties will be pointed out in later discussions of the degree-granting departments.



chapter 2

Who Should Study Engineering?

WE HAVE said that engineering is a very broad field. Men and women of different interests and abilities will find satisfactory work in it. Moreover, an engineering education is good preparation for a career in areas where the basic operations may call for little or no technical "know-how." The reason for this is that the habits of orderly thinking and the ability to organize facts and information, which are hallmarks of the engineer, are also needed for success in other fields. One could present a strong argument for the value of an engineering education for general use. However, our discussion will be focused on its applications to the practice of engineering, with only incidental attention to its value as general education.

WOMEN IN ENGINEERING

Those who work in the various fields of engineering have been, largely, men. This is for the reason that men seem to be better adapted than are women to carry on the entire demands of most engineering fields. However, we find women doing every kind of job that men can do, in foreign countries and in this country. And many of the traditional notions that limited or restricted the activities of women in the professions are undergoing change.

Women with the proper aptitude, interest, and industry, master the work of an engineering curriculum as satisfactorily as men. Upon graduation they may take positions in many functional fields and branches of the profession, where they do make successful careers. Generally, women have not advanced into the areas of construction and manufacturing where the management of machines, materials, and men is a requisite. The basic factor that has limited the employment of women in engineering is the reluctance of an employer to invest time and money in the training of an employee who, in all probability, will leave in a year or so to marry and make a home. This will always be true. And there will be exceptions. Any young woman who looks at engineering as a career should face this fact.

APTITUDES

As a rule, anyone who can complete the educational requirements for graduation from an engineering college can find a position in engineering which he can fill satisfactorily. For this reason we may estimate a man's probable success as an engineer in terms of his ability to graduate. That is to say, if he cannot do the engineering course work he cannot graduate and, therefore, cannot become an engineer. There are exceptions where men failed to complete their engineering courses satisfactorily yet were able to attain success in engineering work. In many such instances the college failure was caused by something other than lack of ability.

An engineer's work as well as his studies requires above-average ability to think clearly in quantitative terms. He must make precise measurements, set up formulas and solve mathematical problems, deal with statistics, plot graphs. He must know the properties and uses of materials as well as the basic scientific laws and principles upon which those properties and uses depend. He is expected to have sound financial judgment and a knowledge of the feasibility and practicability of all that he undertakes. He is often called upon to organize and direct the work of others.

We shall explore in more detail the aptitudes, interests, and personality that a successful student in engineering would have. Aptitudes for the following have been found to have some significance: (1) learning higher mathematics, (2) space visualization, (3) manual skill.

Mathematics. A man's aptitude for learning higher mathematics such as algebra, trigonometry, analytic geometry, calculus, and their applications is the most significant index of his ability to succeed in an engineering curriculum. The reason seems clear. Mathematics and its applications appear throughout the engineering curriculum. To be successful in higher mathematics one must have the ability to reason clearly, accurately, and logically. He should be orderly and systematic. These mean more than the arithmetical skill of a bookkeeper or a clerk. The most essential element seems to lie in the type of reasoning. A mind that follows the mathematical way of reasoning will also master the engineering courses. No man need be in doubt on that point. If his grades in high school algebra have not been above average it is probable that he will have to work very hard to master college mathematics. Poor grades in mathematics and the fundamental science courses of the first two college years are apt to lead to discouragement which may start a train of events that ends in withdrawal from college. Anyone with a yearning for engineering who has doubts about his mathematical ability should take a mathematics aptitude test. This can be obtained and administered by his high school teachers.

Space Visualization, which is the ability to perceive the sizes, shapes, and relations of objects in space, and to think clearly about those relations, is an important asset to an engineer. However, men who have this trait weakly developed can master an engineering curriculum without serious difficulty. After graduation they may choose fields of work where the lack of that ability may not be a serious handicap. Men who choose the technical fields, such as design, development, research, and experiment, will find facility in visualization a significant factor in their success. It may be rated as one of the *plus* values—a man can get along without it, but he will be a stronger and better engineer with it.

This ability to visualize appears in a variety of ways. Essentially, it means translating a two-dimensional sketch into a three-dimensional picture. Solid geometry in high school and descriptive geometry in college are courses that test one's ability to visualize. In the practical field, examples would include a person who is ingenious at finding what is wrong with a machine, or who is able to perceive the relationships between parts of a complicated mechanism, or one who is adept at cutting and fitting intricate shapes such as are handled by a sheet-metal worker. Clearly, this aptitude would be very significant in many trades. As pointed out before, an engineer can get along without it, but he who has it is apt to forge ahead of his otherwise equally endowed associates.

Anyone who is in doubt about his aptitude for dealing with spatial relationship may arrange to take one or more of the well-authenticated tests which have been developed for that purpose.

Manual Skill. Aptitude for acquiring manual skill—that is, the ability to perform operations with one's hands with considerable dexterity—is a very useful but scarcely essential trait for an engineer. During the engineering graduate's first year or two on the job, a better-than-average ability to do things with his hands may help to bring him to the attention of his superiors, which may lead to earlier and better opportunities for advancement. Also, manual aptitude may be helpful in judging the performance of others. This aptitude, like space visualization, is a *plus* quality for an engineer. He can succeed very well without it; it cannot replace mental ability; yet the man who has it with the other essentials will be a better engineer than he who lacks this manual ability. There are tests which one may take to test his manual aptitude.

Engineering Drawing. Aptitude for engineering drawing and manual arts have some significance to the prospective engineer, but the ability must be evaluated carefully. In drawing, if the proficiency lies only in ability to make neat and accurate plans, side and end views of simple objects, the good drawing grades are not such important indicators of engineering aptitude as they would be if the student were able to make difficult sectional views or details of hidden and intricate portions. In other words, the first indicates manual dexterity and neatness, the second, some space visualization.

Similarly with shop work such as boys do in high school, manual skill and dexterity in sawing and fitting boards are not indicators of engineering aptitude. But the ability to visualize, plan, and make a piece of equipment, even though done with only fair workmanship, does indicate one of the *plus* engineering aptitudes — the ability *to see things before they are built.*

Many people mistakenly base estimates of a young man's probable success in an engineering college on his manual skill, his ability to make model airplanes, or his liking for machinery. It cannot be emphasized too strongly that these traits, though desirable and useful, must be accompanied by the aptitude to master an engineering curriculum. Furthermore, this interest in and liking for things mechanical is not an uncommon trait in boys. Therefore, parents should be cautious about giving too much weight to this when estimating their son's future in engineering.

Chemistry and Physics are important subjects in an engineering curriculum, and a young man's high school grades in these subjects are a useful measure of his probable success in the same subjects in college. Frequently, a student's high school work has not included chemistry and physics. In that event he would be wise to take both a chemistry and a physics aptitude test. They can be arranged by his high school teachers. These tests are designed to measure abilities that are presumed to be indicators of one's aptitude for learning the subject.

Neither chemistry nor physics is as significant an index of one's aptitude for engineering as is mathematics. Yet they call into use and develop certain abilities that are used in subsequent engineering courses, such as the ability to organize related material; the ability to answer questions after reading pages of printed material; the ability to set up and solve problems when the essential data is given, frequently in an indirect form; the ability to make arithmetical and algebraic computations such as are common throughout the engineering curricula.

English. Aptitude for learning English should have some attention. Boys are traditionally *poor* in grammar. Yet engineers must write clear and logical reports and present good oral discussions. So a good vocabulary and a better-than-average high school grade in grammar are distinct assets to the prospective engineering student. This is not as essential to success in the engineering curriculum as is evidence of ability in mathematics. Yet the boy who has a small vocabulary and a poor command of grammar may not have the general mental alertness that is needed in an engineering curriculum, and he certainly will be handicapped in his reading assignments. However, the man who is very fluent in his use of English, and who writes readily and well, may become dissatisfied with the details and mental discipline of an engineering curriculum.

INTERESTS

Interest and aptitude are closely related. As in the case of the chicken and the egg, it is hard to say which is first. If we had a way to measure a man's desire, which is the manifestation of interest, we could predict his achievement. Interest means more than glamour or a popular fancy. It is a deep-seated urge. Oftentimes young men are intrigued by the popular appeal of an engineering achievement such as the airplane or radio. Sometimes the attraction goes further and we find them constructing model airplanes and homemade radio sets. A young man and his parents infer from this that he is *interested* in engineering. Perhaps he is, but he should undergo further testing.

Importance of Interest. There are several reasons why this matter of interest is so important. First, we like to do what interests us and we do not care to do what does not interest us; this is one reason why a prospective engineering student should know whether engineering will interest him. A second and very important reason is that everyone would like to be working with congenial people in suitable surroundings; again, the student should know whether his likes and dislikes are similar to those of engineers because some of those engineers will be his colleagues. Third, as mentioned above, a man can learn to do best those things which interest him most, and he is likely to develop an interest in doing those things that he seems to do best. A fourth reason for inventorying one's interests is that the study and investigation may uncover and open up other fields that might have been overlooked.

Test for Interest. Ascertaining a person's interest for engineering is not easy. There will be a considerable amount of testing, but the results in the form of personal satisfaction will be worth the effort. One may do three things: (1) Take a test for vocational interest. (2) Review his like or dislike for certain courses in high school. (3) Get a job at work that engineers do.

The use of interest tests will help a person recognize his interests more logically and more quickly than he can without the tests. However, interests change rapidly during the formative years of youth and one should not make a final choice of his vocation on the basis of a test taken at age twelve, for example.

There are some widely known and frequently used tests on the market. One of these is the Strong Vocational Interest Blank for men and women. It does not measure specific interest. It compares a person's interest with the interests of more than forty groups of professional people, such as mathematician, banker, engineer, minister. Another test is the Kuder Preference Record which shows the tested person's interest in ten occupational groups — outdoor, mechanical, computational, scientific, persuasive, artistic, literary, musical, social service, and clerical. A third test is the Brainard Occupational Preference Inventory which shows one's interest rating in twenty-eight rather specific occupational groups. For other tests, see the Appendix.

Regarding high school courses, if a person enjoyed algebra, geometry, mechanical drawing, physics and chemistry, it is probable that he would like the corresponding courses of an engineering curriculum. There should be positive evidence that he *actually* liked those subjects. This liking would show in his spare-time activity. He would make more than the required number of drawings; he would try to make frequent use of algebra; he would try all sorts of experiments in chemistry and physics.

It should not be hard to find a job at work that engineers do. This would include office work at computing and drafting; field work on a survey party as rodman or chainman; assistant timekeeper on a building, bridge, pipeline, or other type of construction; factory work, such as materials clerk in a plant where machines are built; a few weeks in a vocational summer camp. The experiences will be brief, fragmentary, and oftentimes inconclusive. They will help any person who is giving serious attention to the choosing of his career.

Interpretation of Tests. The determination of the meaning of the foregoing tests and experiences calls for a great deal of experience and knowledge. In fact, the written interest tests must be taken under an experienced guidance counselor such as one would find in his local high school. However, if the tested person's score on the interest test was not positive for engineering or a related occupation, or his interest in the key high-school subjects only lukewarm, or his reactions to his experience with engineering work indifferent, he should count his *interest* in engineering as *not proved, possibly doubtful.* If he decided to study engineering in spite of his uncertain interest it would be very important that he have a proved aptitude for the significant high school subjects, or have a very strong determination and willingness to work at college subjects which, in the beginning at least, might prove uninteresting. This is very important because a large number of the failures in college may be traced to lack of interest strong enough to carry the student through the early disappointments and reverses that come at the beginning of his college work.

Personal Qualifications. Because engineers find work in so many fields there is no particular type of personality that is essential to success in engineering. There is a general notion that engineers are lone workers, inclined to be thoughtful, retiring, and somewhat individualistic, with a preference for work with machines, books, and symbols rather than with people. The facts are that large numbers of engineers in manufacturing, construction, selling, and other fields, are called upon to work with and supervise others, and the most successful engineers, as in other lines of work, are the men who, in addition to doing an excellent technical job, are also the leaders of men and the organizers and managers of enterprises.

There are certain traits that an engineer should have. He should have a liking for accuracy, for exactness, and for detailed and persistent study. Many of his problems are long and involved. He must have the patience and persistence to keep himself at those problems until they are solved. Nervous and erratic people, even though mentally keen, are apt to become impatient with such work. He must be honest in the sense that he can weigh all facts judiciously and arrive at a fair result. He should have a sound and healthy body. During his early assignments a young engineer will be called upon to do considerable manual work. Some of this will be out of doors in all kinds of weather; some will be in large factories or mills that are hot and dusty. Most of his later assignments may be in more pleasant surroundings. His advancement may depend upon how creditably he does his first assignments, so it is important that he be able to endure some hardships and unpleasantness.

SUMMARY

The following outline gives the essential characteristics which should be possesed by a man who hopes to be successful with an engineering curriculum. When considering these points it is understood that a man must be able to earn a minimum passing grade in a given subject, regardless of the signficance of that subject, if he expects to graduate.

Aptitudes

1. **Mathematics.** Ability to learn this subject as shown by a better-than-average high school record or equivalent test scores is essential.
2. **Chemistry and Physics.** Aptitude for these subjects is not as significant as is aptitude for mathematics, but a large number of scholastic failures in the engineering colleges include one or both of these subjects.
3. **Visualization.** This is an important but not an essential trait. The best engineers will possess it strongly. Those with the trait less strongly developed should choose jobs where that ability is not an important requisite. Some of their engineering courses may be harder to master because of weakness in this trait.
4. **Manual Skill.** This is a desirable but not essential trait. Those who possess it may use it to advantage. Those who lack it will not be affected adversely if they choose work where manual skill is not an important requisite for success.
5. **Mechanical Drawing.** If this indicates ability to visualize, it is an important but not an essential trait. It has greater significance as an interest factor.
6. **English.** This aptitude is very desirable but not essential. Too much proficiency in English may make one restive in a technical curriculum. Too little proficiency can make learning slow and difficult.

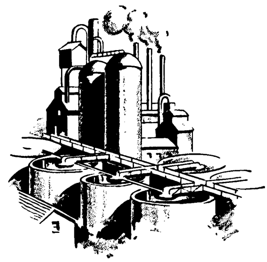
Interests May Be Tested By:

1. Vocational interest tests.
2. Like or dislike for mathematics, physics, chemistry, and mechanical drawing. This may be different from ability to master these courses, yet should be closely related to that.
3. Like or dislike for work that engineers do, based on actual experience at such work.

Personal Qualifications, Personality

1. Honesty and fairness in weighing facts.
2. Patience, persistence, and little tendency to be flighty.
3. A liking for accuracy and exactness.
4. A sound, healthy body.

Other Important Traits. In conclusion, it should be re-emphasized that we have been seeking to point out the traits which differentiate an engineer from a man in another field. We have purposely refrained from discussing a large number of traits that must be possessed by successful men in all walks of life. Failure to discuss such things as judgment, common sense, initiative, resourcefulness, efficiency, thoroughness, character, integrity, and many others, does not mean that they are not important. Those are traits that all successful men must have. In addition, the successful engineer should be strong in the traits that we have emphasized.



chapter 3

The Various Engineering Departments

WE WILL consider the engineer's fields of work from three points of view. First, there is the familiar division by *departments,* such as Civil, Electrical, Mechanical Engineering. Second, we have classification by *industries,* such as automotive, agricultural machinery, construction, public utility, paper making, steel, textile. Third, we can classify the engineer's work according to the *function,* or special purpose, that is performed, such as design, construction, development, research, and selling.

The best-known classification of the engineer's work is that which groups it by degree-granting departments. In these departments the courses of study, commonly known as curriculums, grow out of the special technical needs of the engineers who practice in the designated field. In most engineering colleges of the United States the standard college curriculum which leads to the B. S. in a named branch of engineering consists of four years, each nine months in length.

In many of these colleges the courses of the first year are the same for all engineering curriculums, and include mathematics, chemistry, English, and engineering drawing. The curriculums begin to diverge in the second year. There is still a common core of mathematics, physics, and mechanics, and the beginning of course work of the major department, such as surveying for Civil Engineering, more chemistry for Ceramic and Chemical Engineering, machine shop and metallurgy for Mechanical Engineering. The number of courses of the major department increases in the third year, and in the fourth year there are few courses outside the major department. Various agencies, particularly the American Society for Engineering Education (ASEE) and Engineers Council for Professional Development (ECPD), have tried to maintain some uniformity in the engineering curriculums by specifying a percentage of course work that should be in each of the several areas of fundamental science, engineering science, humanistic-social studies, and the major field.

The Journal of Engineering Education Yearbook for 1955 gives enrollment and graduation figures for 19 curriculums, and the ECPD Preliminary Annual Report for the year ending September 30, 1955, lists 19 accredited engineering curriculums. These are: aeronautical, agricultural, architectural, ceramic, chemical, civil (including building engineering and construction, sanitary, structural), electrical, engineering, engineering mechanics, engineering physics, geological, geophysical, industrial (including options in mechanical engineering departments), mechanical, metallurgical, mining, naval architecture and marine, petroleum (including petroleum refining, petroleum production, petroleum and natural gas), textile engineering.

This continual splitting of Engineering into more curriculums is receiving increasing and critical attention of ECPD and the National Council of State Boards of Engineering Examiners. In the preliminary report referred to above it is stated that "ECPD continues to favor the general policy of minimizing the number of specially designated curricula, endorsing whenever practicable the utilization of options in major curricula (as Sanitary Option in Civil Engineering) to designate specialization. It is, however, prepared to examine for approval any curriculum that appears likely to satisfy its criteria for an undergraduate engineering curriculum."

The 1955 ECPD Preliminary Report presents some supplemental criteria that have as their object "the assurance of an adequate foundation in science, humanities, engineering science, and introduction to engineering method while providing sufficient flexibility in science requirements to accommodate curricula requiring special backgrounds, such as life science or earth science. They also provide substantial flexibility for expression of the institution's own individuality and ideals. Finally they are regarded as a statement of principles to be applied with judgment in either case rather than with arbitrary rigidity."

That preliminary report then states these supplemental criteria:

a. All curricula shall contain at least the equivalent of one academic year of mathematics and basic science about equally divided.

b. Except as provided in (c) all curricula shall contain at least the equivalent of approximately one year of engineering sciences, including the following:

1. Mechanics of solids (statics, dynamics, strength of materials)
2. Fluid mechanics
3. Thermodynamics
4. Transfer and rate mechanisms (heat, mass, momentum transfer)
5. Electrical theory (fields, circuits, electronics)
6. Nature and properties of materials (relating particle and aggregate structure to properties)

c. Because some engineering curricula are built in part on sciences not included in the preceding paragraphs, such curricula may contain for additional flexibility other basic or engineering sciences appropriate to their fields, to an extent equivalent to one-third of an academic year, in lieu of an equal portion of time otherwise devoted to the engineering sciences listed in [b above].

d. Approximately the equivalent of one-half of an academic year shall be devoted to engineering analysis, design, and engineering systems.

e. The curriculum shall be designated for an integrated sequential study in the scientific and engineering area. The mathematics and the basic science to be used proficiently in the work in engineering analysis, in the study of engineering systems, and in the preparation for creative design.

f. Depending upon the definition of humanistic-social studies, the equivalent of one-half year to one full year of the curriculum shall represent the minimum content in this area. Of this content, at least one-half year shall be selected from the fields of history, economics, government, literature, sociology, philosophy, psychology, or fine arts, and should not include such courses as accounting, industrial management, finance, personnel administration or ROTC.

We will not have time or space to discuss all of the engineering curriculums that are available in the engineering schools of the United States. So, we will choose those of the founder societies and several others that have become well established in many engineering schools and colleges. This list includes aeronautical, agricultural, architectural, ceramic, chemical, civil, electrical, industrial, mechanical, metallurgical and mining.

In this discussion the reader should keep in mind the fact that our purpose is to describe the work and requirements of each department so that the points in which it differs from other departments will be as clear as possible. There are areas that are common to several departments, and men who receive their degrees in one field often take jobs that are commonly listed in another field. For example, large numbers of civil and mechanical engineering graduates are working for aircraft manufacturing companies, and agricultural engineering graduates are found in public works in the field of the civil engineering graduate. There are characterizing differences among these fields of engineering which the prospective engineering student should understand if he expects to base his choice of a curriculum on anything more than chance. And the successful engineer in a given field should have the traits common to all engineers as well as those characteristic of his special field.

AERONAUTICAL ENGINEERING

Aeronautical engineering is one of the most recent of the engineering curriculums. Also, developments in aircraft structures, engines, and materials have been very rapid. All of this, plus romantic interest, plus contact with military airplanes, has turned many young men to this field. However, the profession and industry are now far advanced byond the early days when the progress of flying depended upon adventurous and gifted men. Those who succeed in the technical phases of aeronautics must have a thorough engineering education.

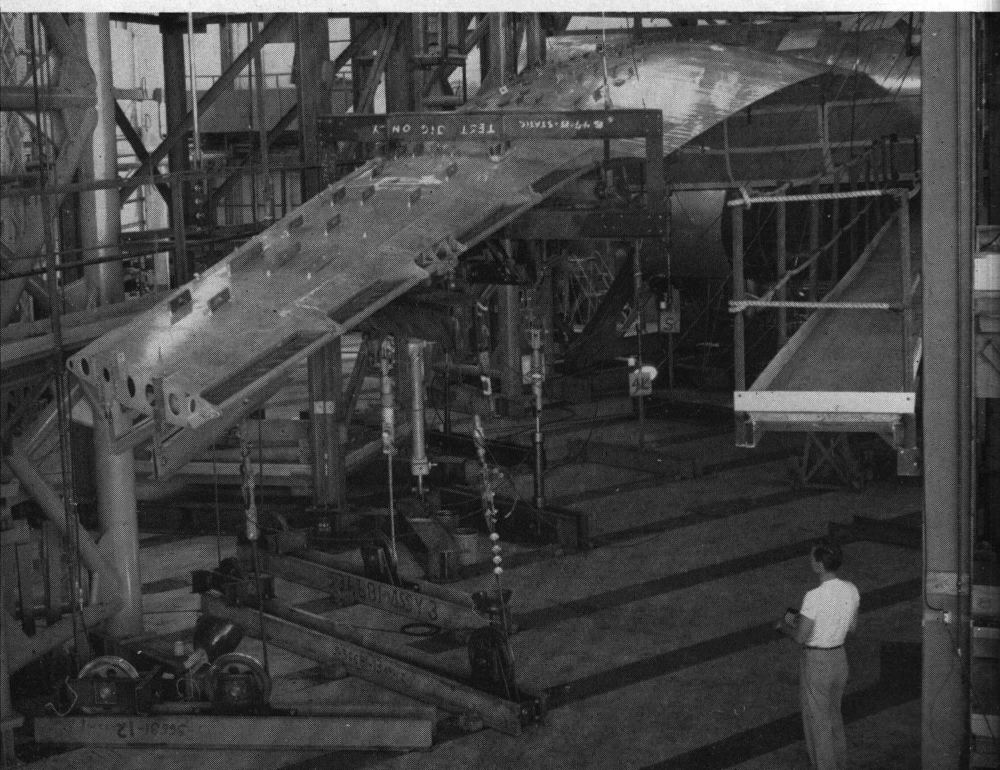
Most of the great developments in this field have come in the twentieth century, many of them during and after World Wars I and II. Since the second war, in particular, huge sums of money have been spent by the government and by private agencies on analytical and experimental studies that have brought bigger, faster, new-type aircraft structures, new and stronger alloys of metals, new types of power plants, and extensive improvements in the older types. Growth of the airplane from the little monoplane and biplane to the huge many-engined passenger- and freight-carrying ship of today is well known to anyone who looks at a television program. But what is not so well known, and of great significance to the would-be aeronautical engineer, is the important part that engineers have played in this development. By extensive research, improved design and better production methods, they have moved the airplane from a custom-made, individually-laid-out machine into a production line creation. The airplane of the future will be designed and built by engineers who know, in addition to the basic engineering courses, mathematics beyond calculus, advanced chemistry and physics, advanced aerodynamics and thermodynamics, indeterminate structures, and advanced properties of materials.

Our picture of the successful aeronautical engineer does not include the ability to pilot an airplane — although this is a useful ability — nor airport construction, nor the business of air transportation. What he does expect to do is to create, design, develop, and build airplanes. As he looks into the requirements he sees a profession that is still in the process of establishing its boundaries. He sees in the airplane a complex structure whose planning, design, and manufacture call for the solution of difficult problems in stress analysis, fluid flow, aerodynamics, and production methods. This structure is driven through the air by an intricate power plant, conventionally a rotating internal-combustion engine, and, recently, a jet engine. Inside the plane are innumerable devices that are used to send and receive signals, to control the plane, to guard against accidents, and to do many other things. Clearly, the man who would have some responsibility for the design of a complete airplane must study many engineering courses in college. And if he wishes to have a place in the manufacturing of planes he must also know a great deal about production and manufacturing processes.

Fields of Aeronautical Engineering

Most aeronautical engineers take jobs in areas related to the aircraft industry. This includes employment with the federal government and with private companies. The former has very extensive research laboratories and pilot plants where all types of studies are carried on. Also, private companies and universities have large government contracts whose objective is the development and improvement of such devices as aircraft and guided missiles. With both of these the emphasis is on research in such fields as Aerodynamics, Hydrodynamics, Propulsion, Aircraft Loads, Airframe Construction and Materials, Flight and Pilotless Airplanes. Some of this work is done on the drafting board, in the calculating room, in wind tunnels, or on the airplane in flight. In every instance men are needed who have above-average ability in the mathematical and physical sciences.

An engineer observes the static test on an airplane during the wing-bending phase of the program. Note devices for applying loads. The wing tip went through an arc totaling 32 feet during the tests. (Courtesy Boeing Aircraft Co.)



The production line at an aircraft plant shows several twin jet fighters being fabricated in the final assembly area. In addition to planning and designing the aircraft, the engineer supervises its manufacture. (Courtesy McDonnell Aircraft Co.)

Similarly, the aircraft manufacturing companies have places for men who will work on the design and production of planes that are to be built, as well as on research and development. Here the aeronautical engineer does such work as: Aerodynamics — performance calculations, stability, control, and flight test analyses; Flight Tests — both operations and instrumentation; design of fuselage structure and wing structure; for Structures — check of drawings, computation of stress analyses, evaluation of new materials; in Production — selection and design of tools, assembly line planning, and use of proper tools.

Characteristics of Aeronautical Engineers

The successful aeronautical engineer should have the following traits: (1) ability to visualize; (2) better-than-average mechanical ability; (3) better-than-average aptitude for mathematics and the physical sciences; (4) the type of mind that can work well with both the abstract and the concrete

Professional Organization for Aeronautical Engineers

The Institute of Aeronautical Sciences, which was founded in 1932 and patterned after the Royal Aeronautical Society of Great Britain, is the professional society for aeronautical engineers. Its objective is to advance the art and science of aeronautics. Membership in the organization begins with the grade of Technical Member. Such members shall be former student members who have graduated and others engaged in scientific or engineering work in aeronautics, or fields closely related to aeronautics.

The institute has approximately 70 student branches in the United States. Membership in a student chapter (student member) calls for no dues, and entitles the student to subscribe for the Review (technical publication of the institute) at half price. Upon graduation the student member may become a technical member by paying annual dues. There is no entrance fee.

AGRICULTURAL ENGINEERING

An agricultural engineer is one who devises and utilizes machinery for multiplying man's power in the agricultural industry, which is the industry engaged in the production of raw materials used for food, shelter, and clothing. Agricultural engineering had its beginning as a department of farm mechanics in agricultural colleges. It is still closely allied with agricultural education, and in many colleges the department of Agricultural Engineering is administered jointly by the deans of Agriculture and Engineering. This dual relationship and responsibility has posed many problems of curriculum content and organization as the department has moved forward in its program to achieve recognition as a professional engineering department. By 1954 it had been accredited by ECPD in 24 colleges of the country.

The application of engineering methods in agriculture, often referred to as mechanization, has brought immeasureable benefits. Among these are: (1) increased productive capacity of the farm worker, (2) change of the character of labor on the farm, (3) aid in shortening the average length of the working day, (4) contribution to the comfort, health, and convenience of farm life, (5) sharp reduction of women as laborers in the field.

Three notable milestones in the mechanization process have been Eli Whitney's cotton gin, which made a change in the processing or manufacturing of a product already harvested; McCormick's mowing machine, which was the first machine with moving parts that moved in a field; McCormick's harvester, which carried the grain until a sheaf had accumulated, then bound it and kicked it off. These machines released men from hand labor with scythes and rakes.

The next and perhaps greatest advance in the application of power to the farm has followed the development, adaptation, and quantity production of the internal combustion engine, first the gasoline engine and later the diesel engine. Here the source of power is the fuel which runs the engine which, in turn, propels the machine over the ground and, at the same time, furnishes power to do the work of picking corn, baling hay, threshing grain, and many other operations.

It is obvious that the credit for these mechanical developments must be shared by many engineers, manufacturers, farmers, implement dealers, and others. Also, there is a fairly clear line between the interests and functions of the agricultural and mechanical engineers in this development. The latter is concerned with development, design, manufacturing, and applications to uses that are primarily industrial. The agricultural engineer is interested in those phases of development and design that relate to the application of power to agricultural uses. Generally, the actual manufacturing processes are handled by mechanical engineers.

Development of farm equipment requires actual testing under operating conditions. Here, an agricultural engineer is making field tests on a new type of forage harvester, using electrical resistance strain gauges and electronic recording equipment.

Fields of Agricultural Engineering

The fields of specialization of agricultural engineering departments for purposes of optional undergraduate work, graduate work, research, field service, etc., are divided into Farm Power and Machinery, Farm Structures, Rural Electrification, Soil and Water Conservation. In many curriculums a group of technical electives is designated for students who wish to specialize in one of these areas.

Farm Power and Machinery. Courses in preparation for this option include Kinematics, Machine Analysis, Design of Machine Elements, and Agricultural Machinery Design. Those who work in this field are engaged in the design of machines, and the selection and efficient application of power to the farm through various pieces of mechanical equipment, as well as the sale and servicing of these implements. The annual bill for the purchase of farm machinery is large, and the depreciation is rapid. Companies that manufacture and sell farm equipment employ agricultural engineers to work with the sellers and users of this equipment to improve the product and its service and to lengthen its life.

Farm Structures. Courses in preparation for this option include Heat Transfer, Refrigeration and Air Conditioning, and Elements of Structures. Work includes the planning and construction of farm buildings, and providing the water, light, heat, sewage disposal, and ventilating systems for these buildings and related farm operations. Timber, concrete, steel, aluminum, and other materials in new and improved designs are in use on the farm for houses, barns, hog houses, chicken coops, and other buildings. Water from wells and farm ponds is piped into the house, barn, and feed lot. Sewage must be disposed of sanitarily in septic tanks.

Rural Electrification. Courses for this option are similar to those for the Farm Structure option with Application of Electronics replacing Elements of Structures. Perhaps the most striking change in farm living has come about through increased use of electricity. Agricultural engineers who work on rural electrification have the task of utilizing this power effectively in the rural community.

Soil and Water Conservation. Special courses in this area are Design of Soil and Water Conservation Facilities, Soil Conservation and Erosion Control, and Soil Engineering. The work includes drainage, irrigation, land clearing, erosion control, and the necessary surveying. This activity of agricultural engineers has received nationwide impetus and publicity durng the last twenty-five years. We must conserve our natural resources, and soil and water are two of the most important. Employment in this field is largely by the state and federal governments.

Characteristics of Agricultural Engineers

The young man who plans to make agricultural engineering his career should possess the following specific characteristics, in addition to those listed for all engineers: (1) a definite interest in farm life and sympathetic understanding of agricultural problems; (2) an interest in and liking for courses in agriculture; (3) a preference for the experimental and practical aspects of engineering rather than the theoretical and technical, because in the applications of power to the farm there is much that is "cut and try"; (4) a liking for outdoor life on the farm, because agricultural engineers will find their work close to the farm whether it be with machinery, structures, rural electrification, or soil and water conservation.

Professional Organization for Agricultural Engineers

The American Society of Agricultural Engineers is the professional organization for agricultural engineers. Its objects as given in the constitution are: "To promote the science and art of engineering as applied to Agriculture; to encourage original research; to foster agricultural engineering; to advance the standards of agricultural engineering; to promote the intercourse of agricultural engineers among themselves and with allied technologists; to encourage the professional improvement of its members; and severally and in cooperation with related groups to broaden the usefulness of agricultural engineering."

The lowest grade of membership is Junior for which the qualifications are: "Graduate in a professional agricultural engineering course from a school of accepted standing, or one who has equivalent attainments."

There is provision for student branches: "A student member shall be a student regularly enrolled and pursuing an approved agricultural engineering curriculum in a school of accepted standing."

ARCHITECTURAL ENGINEERING

Architectural engineering is a combination of architecture and structural engineering, or a specialized branch of architecture related to civil engineering. Usually, the function of the architect is to create the structure, including purpose, location, convenience, proportion, style, and factors of beauty. He is an artist whose design pleases the eye with a structure that serves a utilitarian purpose.

The structure must have more than beauty — it must have strength; it must be built economically; it must be useful. This

Architectural engineering students discuss a class project which deals with the materials and method of construction of a small modern building. This step follows the drawing of plans, as shown on the walls. Later, the architectural engineer may supervise the construction of this and similar buildings.

demands a wide range of technical skill. Generally, architects are not qualified to make the necessary analyses and to design the supporting structure and structural details. For this they call on civil engineers who have specialized in structures.

The architectural engineering curriculum has been established to prepare men to conceive, plan, and design the structure and its appurtenances. The graduate has received fundamental training in architectural design, structural design, building construction, mechanical equipment of buildings, and materials of construction, which qualify him to handle the complete design of the building and supervise its construction.

The design of modern steel and concrete office and industrial buildings, hotels, churches, public buildings, and monumental structures requires a careful study and a thorough understanding of the heavy loads which the foundations and framework must carry. In the early days before the era of steel construction, relatively little scientific or mathematical attention was given to the design of the foundation or the superstructure. In those days making a new design involved a comparison wih existing structures, plus experience and judgment. But the advent of steel construction changed all of that. Now there must be an analysis of all stresses caused by all loads, such as weight of structure, loads to be imposed, wind, vibration, and others. This analysis is preliminary to determination of the amount of steel or other structural materials (weight, size, and shape) that is required in roof trusses, columns, and floor members, to make the building safe.

In addition to being safe the building must also be economical, convenient, and attractive. Furthermore, the complex problems in connection with planning of the building services — heating, ventilation, lighting, and others must be understood by the architectural engineer so that he can make provision for those services. The details of their design would be handled by specialists in each of those fields.

Fields of Architectural Engineering

There are several major fields in which architectural engineers are engaged. These include:

Architecture. Some enter architects' offices where they work on the architectural or structural, or both, phases of design. Their experience is apt to include drafting and design, and inspection while acting as the architect's representative on the construction job. One of the significant aspects of the architect's practice is that he usually serves as a consultant, is the owner of his own business, and deals with his clients personally on the basis of a fee instead of a salary.

Construction. This broad field takes many architectural engineering graduates each year. They work for the contractor as timekeeper, checker, or instrumentman, for the owner as inspector, for the architect as inspector and, when experienced, as superintendent. Here is a field where practical or trade experience, such as work at carpentry, bricklaying, and the like, are very helpful to a young engineer who seeks a career in the construction field. He will be inspecting and checking the workmanship of skilled craftsmen. They will respect his judgment, and he can do a better job, if he has had some actual craft experience.

Engineering Sales and Service. Here, as in several engineering fields, there has been a growing need for engineers who can bring the results of technological improvements to the user and consumer. For example, millwork companies have engineers on the road who confer with and give technical advice and service to dealers and users of their products. Manufacturers of synthetic lumber, fixtures, sound proofing, acoustical boards, and other materials, offer a similar service. Frequently, this service includes the supervision of installation as well as the selling. These jobs offer many opportunities to combine engineering and business in a pleasant and profitable manner.

Structures. This includes the planning, design, and construction of buildings in steel, concrete, reinforced concrete, brick, timber, and other building materials. Generally, the architectural engineer confines his structural work to buildings, such as stores, apartment houses, hotels, theaters, and office buildings, leaving bridges, dams, and the like, to civil engineers. Work assignments include drafting, checking, calculating, estimating, inspecting, testing. Most of this is office work.

Industrial Design. This new field, which combines art, science, a sense of proportion, creative ability, imagination, and natural mechanical sense to an unusual degree, has grown up during the last decade. We shall list it under the architectural engineering fields although it would be fair to say that industrial designers are born, not made. The objective of industrial designing is to create a product which appeals to the senses, does not appear illogical, and will do its job. Probably the common word for this is "streamlining." It seems to offer a promising future for those who have the talent.

Characteristics of Architectural Engineers

The ideal architectural engineer would have a combination of aptitudes for the artistic and the scientific. He should (1) have an aptitude for creative design and a sense of harmony of color, form and design, and materials, part of which can be acquired through training and study; (2) enjoy and have some aptitude for freehand drawing and sketching with pen, pencil, and water color; (3) have an interest and some manual skill in drafting, both architectural and structural, because a large percentage of the architectural engineer's college work is on the drafting board; (4) be accurate and creative in the type of analysis and calculation that is used in structural problems.

Professional Organization for Architectural Engineers

The American Institute of Architects is the professional organization for many of the architectural engineers who engage in activities closely related to architecture. Its objectives as stated in the constitution are: "to organize and unite in fellowship the architects of the United States of America; to combine their efforts so as to promote the aesthetic, scientific, and practical efficiency of the profession; to advance education in architecture and in the arts and sciences allied therewith, and to make the profession of ever-increasing service to society."

Members are chosen from architects who have "the professional qualifications required by the board for admission to corporate membership, an honorable standing in the profession and in his community, and [the ability] to undertake the pecuniary obligations of membership."

Chapters of the institute may make provision for junior associates whose qualifications are: "Any architectural draftsman of good character and reputation living or employed in the territory of the chapter who is able to undertake the pecuniary obligations of a junior associateship and neither is engaged in the practice of architecture as a principal nor is legally licensed or registered so to do . . . An undergraduate or post-graduate student in a school of architecture recognized by the Institute . . . may be admitted . . . to junior associateship as a Student Associate."

CERAMIC ENGINEERING

Practice of the ceramic art is very old. The word *ceramic* came from the Greek word *keramos* which means burned stuff or burned clay. For centuries ceramics was an art and a field of the skilled workman who made objects with his hands. Developments in science and technology have brought many of their applications to the ceramic field. Out of this has evolved Ceramic Engineering which we may call the application of scientific principles to the fabrication of ceramic products; the mining, refining, and processing of raw materials; their manufacture into finished products; and the design, construction, and operation of the equipment required.

The field is not well known to the average citizen. Yet the value of its annual manufactures is large and there are many employment opportunities. The products include everything manufactured from earthy (nonmetallic) minerals. The actual work of the ceramic engineer may be described best by discussing the divisions, or fields, of the industry which are based, in the main, upon the nature of the finished products.

Fields of Ceramic Engineering

Structural Clay Products. This is the ceramic field best known to the general public because plants in which these products are made are surrounded by large open yards in which brick and tile are stored. Products include terra cotta, building brick, structural tile, quarry tile, drain tile, and sewer pipe. In the past this field has been dominated by the "practical" man who grew up with the business. Competition has brought the necessity for new processes and new products at lower costs. Here we find the ceramic engineer taking a hand in all phases of this field including the design and construction of plants, their operation, research, and selling of products.

Ceramic and chemical engineers must make many chemical tests to determine and control the nature, quantity, and quality of products. Here, ceramic engineers are doing fundamental research on clay minerals.

Refractories. Included here are fire clay, silica, chrome, and magnesite refractories, crucibles and muffles, glass pots and tanks, zinc and glass retorts, insulating bricks, refractory cements. This is an important section of the industry because most of the melting processes, such as those in the manufacture of iron and steel, depend upon a furnace lining that will stand up under intense heat. The word refractory means difficult to melt, fuse, or reduce.

Abrasives. As materials used in manufacturing processes are made harder we must develop harder grinding wheels to sharpen the tools that will shape the material. These sharpening devices and some cutting tools are made from silicon carbide and aluminous abrasives by the ceramic engineer.

Enameled Metal. This is used in sanitary enamelware, household ware, walls and partitions, stoves and refrigerators, signs, and many other things. It is a rapidly growing field. Good appearance, ease of cleaning, strength, and freedom from rust are some of the characteristics of enameled metals. The ceramic engineer who masters this field must have a thorough knowledge of the physical and chemical properties of metals and enamels.

Glass. This includes household glass, window glass, building glass and tile, bottles and containers, mirrors, quartz glass, tubing, glass textiles, reinforcement and insulation, electric light bulbs and vacuum tubes, and many others. One of the interesting things in this field has been the development of glass products that have some of the properties of metals, such as pliability with strength.

Whiteware. Included here are tableware, kitchenware, art pottery, sanitary ware, stoneware, chemical porcelain, electrical porcelain, floor and wall tile. At this point the engineer meets the artist whose help he must have in the design of artistic shapes and patterns.

Cements, Limes, and Plasters. This includes portland cement, gypsum products, magnesia and zinc cements, dental cements, plasters, and others. Some of these are in borderline industries where chemists, chemical engineers, and ceramic engineers have interests and claims.

A brief consideration of these fields will make one fact very clear; namely, a thorough knowledge of chemistry and physics is required of the ceramic engineer. This is true regardless of the type of work that he may do in any industry, including research, design, development, operation, or sales.

Characteristics of Ceramic Engineers

The young man who is considering ceramic engineering should have these special characteristics: (1) a positive and better-than-average liking and aptitude for chemistry and physics, because these two subjects, separately and in combination, are the basis for much ceramic engineering theory; (2) an interest in making things and an aptitude for handling tools and instruments; (3) good health and good physique, because some of the early work may be hard, and because of high temperatures and dust at some plants; (4) a definite predisposition for hard and sustained work, some of it manual, and no objection to getting his hands dirty. This is for the reason that there is a variety of plant equipment which the ceramic engineer must maintain and operate.

Professional Organization for Ceramic Engineers

The professional organization for ceramic engineers is the American Ceramics Society. Inasmuch as this is a society for the artist and craftsman as well as the engineer, the entrance requirements do not have the rigorous technical slant of some of the other engineering societies.

The object of the society as stated in its constitution is "to advance the ceramic arts and sciences by meetings for the reading and discussion of papers and publications of scientific literature, and other activities."

Associate members must be persons interested in ceramic or allied industries. Active members must be persons competent to fill responsible positions in ceramics. There are provisions for the establishment of student branches.

CHEMICAL ENGINEERING

Chemical engineering as a distinct profession is so new that the men who created the first college curriculums are still living. By definition we would say that "the chemical engineer is one who is skilled in design, construction, and operation of industrial plants in which matter undergoes a change,"[1] or, "one able to conceive improvements and inventions in terms of chemistry and competent to reduce them to actuality in terms of engineering science."[2] An important part of the chemical engineer's work is to manufacture products using controlled physical and chemical changes on a large (plant size) scale. Some of these changes are made by altering the physical state of the basic raw material; other changes are made through chemical reactions.

The growth of the chemical industry, both in size and the multiplicity of products, has been one of the most amazing developments of this quarter century. There is scarcely an article of our daily life — food, clothing, shelter, medicines — that has not felt the touch of the chemical engineer. These accomplishments have intrigued our imaginations to the point where we are expecting all sorts of developments. The reclamation and use of sewage wastes; the commercial utilization of waste farm products such as cornstalks and straw; the manufacture of synthetic foods; the use of synthetic products to replace metals for small and large objects, including those that must carry substantial loads and resist bending stresses; these are examples of things that are here, and others will follow.

As with many other professions, we find that there was a sort of art of carrying on chemical manufacturing before the discovery of the scientific principles upon which the art was based. At first the practitioners were industrial chemists — men who used chemistry and some practical mechanical engineering. As the industry grew in size and complexity it became evident that a large number of operations were duplicated in many industries. Out of this observation grew the "unit operation," which is the basis of chemical engineering.

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[1] *Chemical Engineering Plant Design,* Vilbrandt, McGraw-Hill Book Co., 1934, p. 1.

[2] *Vocational Guidance in Engineering Lines,* Amer. Assn. of Engineers, 1933, p. 93.

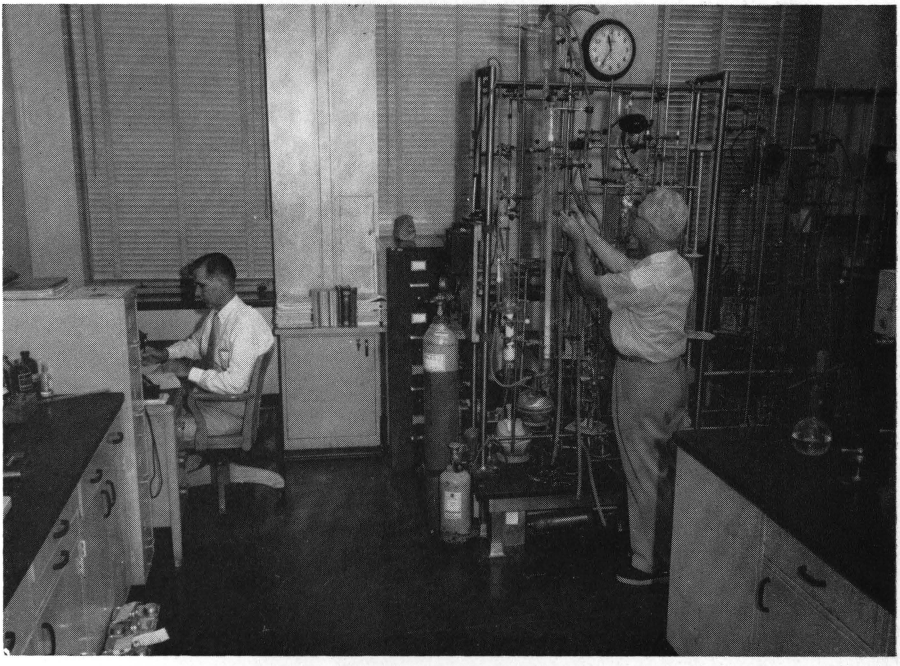
Some unit operations are: mixing, crushing, grinding, size separation, crystallization, filtration, distillation, drying, and many others of a highly complicated nature. Their development has simplified the treatment of chemical engineering because a large list of independent manufacturing processes was replaced by a smaller list of unit operations. Furthermore, specialization in one or more of the unit processes would not limit a man to a particular industry, because each of these unit operations, although carried out in a wide range of types of equipment, is solved by the application of a few fundamental laws. Each manufacturing process, then, consists of an integrated group of these unit operations.

Chemical engineering enterprises lend themselves to the ideal development from the conception through the successive steps of laboratory stage, small-sized model, large-sized or development unit, semicommercial plant, and finally, commercial plant. This sequence or evolution of steps should assure a technically and commercially sound development.

Fields of Chemical Engineering

From the foregoing discussion it can be seen that chemical engineering does not split into major branches as do some of the

Before chemical manufacturing processes can be used on a full-size plant scale, they must have tests in small scale operations in a pilot plant. These chemical engineers are carrying on a pilot plant study. (Courtesy Esso Standard Oil Co.)



other engineering departments. To list special fields we shall turn to the separate industries which include: organic chemicals; heavy chemicals; iron, steel, and coke; meat packing; food products, soap, and glycerine; petroleum products; textiles; nonferous metals; chemical equipment.

Products include acids, alkalies, salts, coal-tar products, dyes, plastics, insecticides, drugs, cosmetics, explosives, fertilizers, leather products, oils and fats, paints, paper, petroleum products, synthetic fibers, rubber products, soaps, chemicals from coke-oven products.

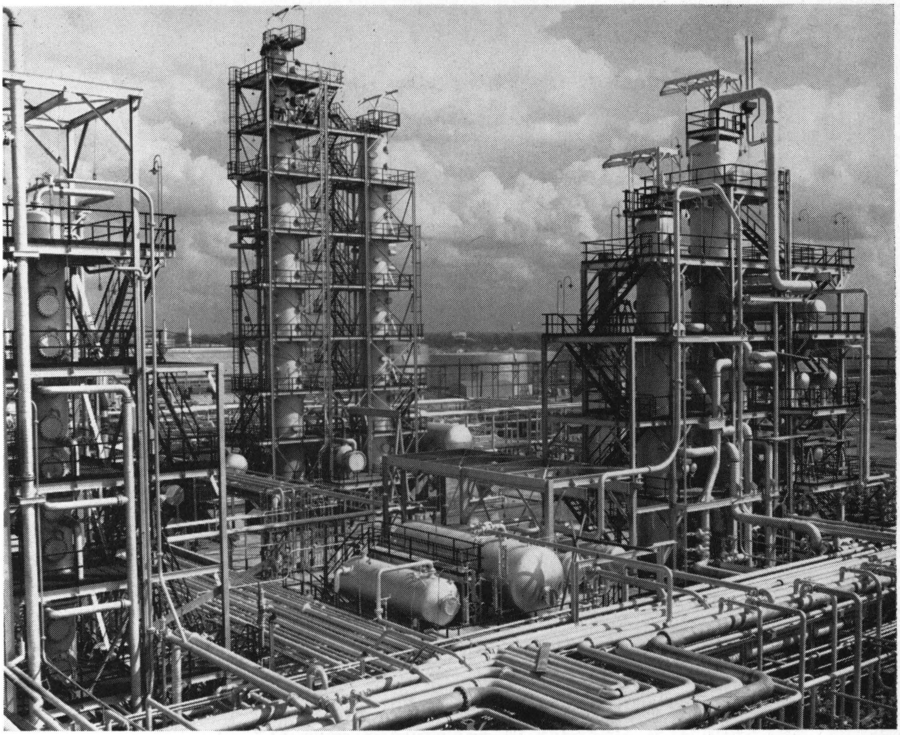
The chemical engineer's work can best be described below by listing some of the functional operations of the industry.

Process Control and Instrumentation. The duties include: (1) tests on qualities of raw material to make sure that they comply with specifications, and to furnish data on their varying composition so that batch proportions may be changed accordingly; (2) tests during the manufacturing process, including temperature, pressure, color, rate of mixing, and others, plus numerous laboratory tests and analyses of samples; (3) tests of the finished product.

Production. Engineers operate and adjust equipment so that it will perform chemical operations efficiently and uniformly, yielding maximum production at minimum cost. During his training period the young chemical engineer will be required to perform many of the manual operations of production. Later, when he has shown that he is prepared for the responsibility, he will be placed in charge of a group of workmen. From that time his progress will depend upon his success in planning and directing the work of others, and in his understanding of the operations, rather than upon any particular manual ability. This line leads to the position of plant superintendent and works manager.

Development. Development in chemical engineering has several stages, beginning with the laboratory stage and ending when the process is ready for utilization on a commercial plant scale. Intermediate steps are the pilot and semiworks plant. Here the problems of application of materials of construction, reaction speeds, time, temperature, mechanical details of operation, and others, go through progressive refinement in preparation for the large-scale operation. The young engineer has a splendid opportunity here to learn the details of manufacturing processes. There are required thorough knowledge of fundamental operations and ingenuity in seeing where and how improvements may be made.

Design. This may follow or accompany development. It involves the adaptation of the experimental or semiworks plant to commercial operation. This refers both to the processes and the equip-



With this maze of pipes and towers the chemical engineer converts refinery gases into useful petroleum products. (Courtesy Standard Oil Co., Baton Rouge, Louisiana.)

ment. It will require work on the drafting board and time in the plant checking performances of the equipment.

Research. Research in chemistry and chemical engineering is very important. Millions of dollars are spent by large companies to discover new products and improve old ones. Huge staffs are employed on this work, which ranges from routinized analyses to the most complex scientific problems. Many men of many abilities are employed.

Sales. Sales covers materials, products, and equipment.

Characteristics of Chemical Engineers

Special traits of the chemical engineer should include: (1) a distinct aptitude for and a real and continuous interest in chemistry; (2) no objection to the characteristic odors, fumes, or high temperatures that prevail, frequently, in chemical plants; (3) good health with no predisposition to pulmonary diseases; (4) keen power of observation and strong inclination to be careful in his work around the plant, because the forces with which he works are out of sight in huge pieces of equipment; (5) an interest in processes of manufacture where the essential operations are carried on unseen in closed containers, in contrast with mechanical manufacturing processes where most of the steps may be observed. It is essential that he be interested in manufacturing, that is, the applications of chemistry to industrial enterprises on a commercial scale. Therein lies the difference between a chemist and a chemical engineer. The interest and training of the former usually does not go beyond the laboratory where new ideas and processes are conceived and tested. The chemical engineer carries on from this point.

Professional Organization for Chemical Engineers

The professional society for chemical engineers is the American Institute of Chemical Engineers. Its objectives, as outlined in the constitution, are: "The advancement of Chemical Engineering in theory and practice and the maintenance of a high professional standing among its members."

The beginning grade of corporate member is Junior Member. Candidates must be more than 21 and not more than 30 years of age. They must have specified amounts and types of experience, or have B.S. degrees in recognized curriculums. The institute has established student chapters in several engineering colleges. Students are entitled to certain privileges and to receive bulletins and other notices of the institute.

CIVIL ENGINEERING

Civil engineering consists of the economic application of the laws, forces, and materials of nature to the design, construction, maintenance, and operation of works and structures; also the research, testing, sales, management, and other related functions. The works and structures include such things as transportation; bridges and buildings; water supply, sewerage, irrigation and drainage systems; river and harbor improvements; dams and reservoirs; surveys and maps.

The civil engineer is a servant of the public, a public service engineer. He plans, designs, and builds the water and sewerage systems that safeguard our health; he plans and builds transportation systems that carry us safely, smoothly, and swiftly, and that bring us food and materials from all parts of the world; he helps in the design and construction of the buildings in which we live and do our daily work; he provides the engineers of industry with orderly, well-planned, correctly designed, and well-constructed facilities with which they produce innumerable manufactures.

In this research project the civil engineer is testing a prestressed concrete bridge beam in a testing machine capable of applying a load of 400,000 pounds. The electrical equipment in the foreground is being used to measure the effects of loads applied with the testing machine.

He helps to make things, such as bridges, roads, dams, and tunnels, that are specific and individual units, each requiring study, special plans, and unique construction arrangements. For example, Boulder Dam could not be built at Fort Peck; the water supply system of New York could not be copied for Chicago. Therein lies a significant difference between the works of the civil engineer and those of his brother engineers in industry. They help to make machines and goods in large quantities for early consumption. Moreover, the factory that manufactures these products must have constant supervision by engineers to maintain a standard quality. The bridge or the dam built by the civil engineer will serve satisfactorily for many years without any attention other than routine maintenance and replacements.

However, highways, bridges, buildings, and all types of public works wear out or become inadequate for modern use. Devastating floods and windstorms destroy in a few hours many lives and billions of dollars' worth of public and private property. Population is growing and there is corresponding expansion and improvement of old areas and development of new areas. All of this calls for an increasing number of better-prepared civil engineers to do the new work and to improve and maintain the old.

Fields of Civil Engineering

We may classify work of the civil engineers according to field or function. Using the list of technical divisions of the American Society of Civil Engineers we find the following fields and functions in which civil engineers specialize: City Planning, Construction, Engineering-Economics and Finance, Highway, Irrigation, Power, Sanitary Engineering, Soil Mechanics, Structural, Surveying and Mapping, Waterways.

Courses of the junior and senior (and graduate) years of civil engineering curriculums are based upon several of these fields. In many colleges advanced courses are offered as options in the senior year. We shall consider these briefly.

Surveying includes mapping, geodesy, and aerial surveying or photogrammetry. All civil engineers receive considerable training in surveying and map making, and many begin their work after graduation on the surveys which are the beginning of most engineering projects. A number have made careers in the fields of surveying and mapping, principally with the federal, state, or local agencies.

Highways and Railways have related problems, so they are combined frequently under *Transportation.* This work includes the planning, location, design, construction, and maintenance of roadbeds, bridges, culverts, tunnels, and grade separations. Work with railways is largely private employment, while that with highways is largely public.

Everyone who drives an automobile knows that we need better — wider, smoother, stronger, safer — highways. While toll roads attract attention, and they are important, the big job of the civil engineer in Transportation is in the daily search for new materials, new methods, new and better ways of using all materials. The need for civil engineers to do these things is very great and the supply too small.

Hydraulics deals with the planning, design, and construction of dams, reservoirs, and systems of conduits or canals for impounding and distributing water for municipal supplies; the reclamation of swamplands and the control of rivers; the planning, design, and construction of water power and irrigation projects; river and harbor improvements, and many others.

Sanitary and Water Supply deal with the removal, treatment, and disposal of wastes from households and factories, and of storm water from cities and towns; the collection, treatment, and distribution of public water supplies. The problems of public water supply and waste disposal are very closely related, so we find these two branches combined frequently in the engineering curriculum and in the city administration. There is a growing realization of the great importance of these two subjects and the related field of preventive medicine, so there has evolved a new name, sometimes designated Public Health Engineering.

Structures enter more or less into the work of all branches of civil engineering. Specifically, this branch has come to mean the special technique required for the design and construction in steel and concrete of many bridges, modern industrial buildings, and skyscrapers. Because of the necessity for economy of design and construction, and for the safety of the completed structures, such work can be entrusted only to skillful specialists.

Characteristics of Civil Engineers

The typical civil engineer should choose this field with the following points in mind: (1) A career in civil engineering still offers an opportunity for outdoor work with variety of activity and environment. In the past this meant a roving existence and a type of life that appealed to many young men. Those opportunities for travel and nomadic living are not so numerous as they were fifty years ago when every civil engineer got his start in a camp. Enough such assignments are available to satisfy those who choose the out-of-doors life. On the other hand, there are equally interesting jobs for men who prefer to remain indoors. (2) To an increasing extent the engineering on public works of all types is becoming a function of some governmental agency. This means that a large percentage of civil engineers, probably more than 50 per cent, may except to become employees of some unit of government — federal, state, county, city. (3) Because civil engineers do have many contacts with the public, they should have personalities that help to make those relations pleasant. (4) A typical civil engineer does not enjoy manufacturing and its mass production methods. (5) He prefers to deal with static (resistance to motion) forces rather than with the dynamic forces of moving parts.

Professional Organization for Civil Engineers

The American Society of Civil Engineers is the professional organization for civil engineers. Its objectives, as stated in the constitution, "shall be the advancement of the science 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."

Members are chosen from the ranks of civil, military, naval, mining, mechanical, electrical, or other professional engineers, architects, or marine engineers. The lowest corporate grade is Junior Member for which the requirements, as stated in the constitution, are active practice in some branch of engineering for at least four years, or graduation from a school of recognized standing; at least twenty years old.

The society has established student chapters in the majority of the schools of engineering in the United States. In addition to numerous technical and professional privileges and contacts, student membership entitles an applicant to a reduction in fees when he applies for corporate membership after graduation.

ELECTRICAL ENGINEERING

Electrical engineering is young both as a science and as a practice or art. The first practical application of electricity and magnetism came in the early telegraph systems which followed Morse's discoveries, shortly before 1840. This was followed by Bell's telephone in 1876 and Edison's development of the electric generator and the incandescent lamp in the early 1900's. The World's Fair at Chicago in 1893 really opened people's eyes to the electrical progress that had been made and gave a hint of what might be ahead. Since that time the results of the discoveries and inventions in the realm of electricity have had a marked influence on the lives and habits of people in all parts of the civilized world. It is not exaggerating to say that without these inventions modern industrial achievements would have been impossible. Everywhere we see astonishing applications of recent electrical developments. The photoelectric cell in countless uses, television with commercial usage, the X-ray in industry, electric welding replacing riveting, transmission of pictures by wire, radar, and numerous automatic controls — these are a few of those developments.

Fields of Electrical Engineering

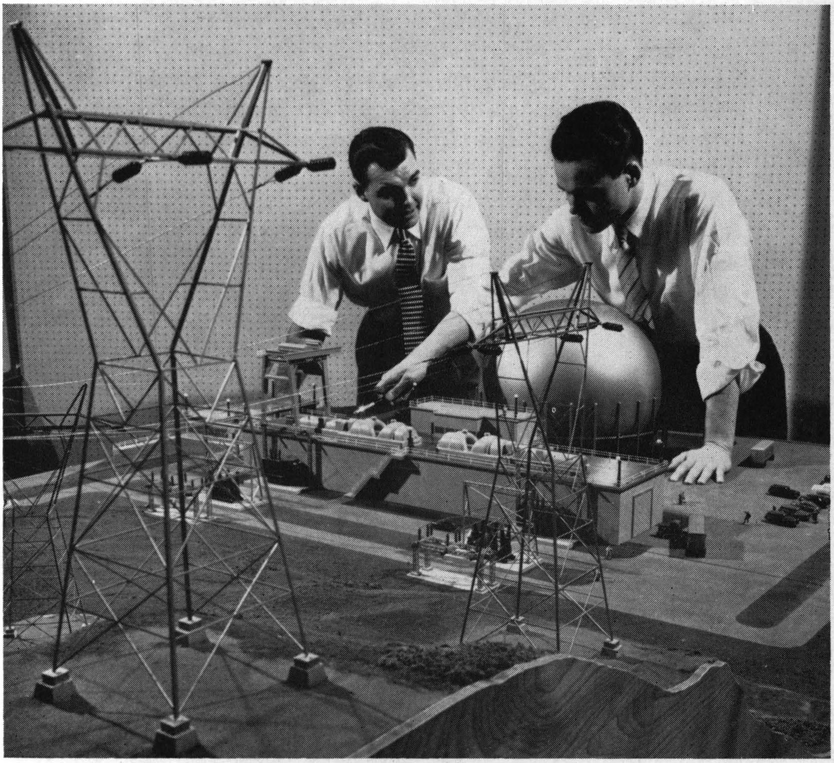
There are several fields of specialization in electrical engineering, each requiring a high degree of specific knowledge. The American Institute of Electrical Engineers has the following technical committees: Automatic Stations, Communications, Education, Electrical Machinery, Electrical Welding, Electrochemistry and Electrometallurgy, Electrophysics, Instruments and Measurements, Applications to Iron and Steel Production, Production and Applications to Marine Work, Applications to Mining Work, General Power Applications, Power Generation, Power Transmission and Distribution, Protective Devices, Research, Transportation.

The electrical industry and electrical engineering may be divided, for convenience, into two main fields. One includes the applications of electricity to light and power where large values of current at low or high voltages are used for such equipment as power generators, motors, and welding apparatus. The other covers the application of electricity to its uses in communication where there are minute currents at minute voltages such as are used in telephone, telegraph, radio, and electronic equipment.

Subdivisions within these two broad fields of power and communication have been designated by specialty names, and several are recognized as options for seniors in the curriculums of many electrical engineering departments.

Illumination includes the conversion of electrical energy into light, the designing and manufacture of light sources and reflecting media, and the planning and installation of lighting systems. Tremendous progress has been made in this field. People expect better lighting in homes, factories, streets, and, most recently, on the highways. In addition to these utilitarian uses, electricity is

Two electrical engineers observe a model of the plant and apparatus that are required for the generation and distribution of electricity. This includes power plant, generators, transformers, transmission towers, and lines. (Courtesy General Electric Co.)



used very effectively in many beautiful and spectacular displays in show windows, public buildings, and exhibitions.

Communication covers telephone, telegraph, and radio, including television, wire and wireless transmission of pictures, wireless-telephone communication with ships and airplanes, and others. It would be fair to say that this field typifies electrical engineering in the popular mind.

Electronics is the practical use of the flow of electrons through space. The principle has many applications, such as taking measurements, inspection and sorting of parts and materials, welding control, motor-speed control, voltage regulation, induction heating, dehydration of food, rectification and inversion from a-c to d-c power, guided pilotless airplanes and guided missiles, and others.

Transportation covers the uses of electricity for vehicles, wires, and track that are used to carry people in trolley buses, trolley cars on tracks (rapidly disappearing), and railroad trains. As our cities grow, the rapid and convenient movement of people by public transit becomes an increasingly important matter. On the railroads the electrification of sections, particularly those adjacent to large cities, has continued. Recent advances in the use of diesel-electric and steam-electric motive power have brought new electrical problems. Automatic train control is another electrical engineering problem in this field.

Power (generation, transmission, distribution) becomes more important each day as the federal government pushes its program to bring cheap electricity to everyone who would use it. The slogan seems to be "bigger and better" — bigger generating units, higher voltages, larger networks for transmission, longer transmission distances, all of which bring new and challenging problems for electrical engineers.

Manufacturing includes every type of electrical equipment from the heavy machinery used in power plants and in transportation to the very delicate devices used in telephones and radios. There is a tendency everywhere to replace mechanical with electrical power. This introduces problems in design and manufacturing that must be shared by electrical, industrial, mechanical, and other engineers.

Characteristics of Electrical Engineers

Qualifying or distinguishing characteristics of an electrical engineer are: (1) mathematical aptitude above that of engineers in other departments, particularly in the quality of abstract reasoning; (2) a liking for physics; (3) a leaning toward the theoretical and

This electrical engineer is receiving data on tests of radar height-finder. Radar's energy is concentrated in a narrow beam like that of a searchlight and is powerful enough to light fluorescent lamps one hundred feet away. (Courtesy General Electric Co.)

scientific rather than the practical; (4) less interest in the manufacturing operations than in the developmental steps leading up to manufacturing, as indicated by (3). Speaking somewhat figuratively, we may say that most of the problems in electricity are invisible, because electricity is energy without material body, so these problems must be treated and understood through their expressions in the form of symbols. The solution of many of these problems requires the most exacting mathematical analysis.

Professional Organization for Electrical Engineers

The American Institute of Electrical Engineers is the professional organization for electrical engineers. Its objectives as stated in the constitution "shall be the advancement of the theory and practice of Electrical Engineering and of the allied arts and sciences and the maintenance of a high professional standing among its members."

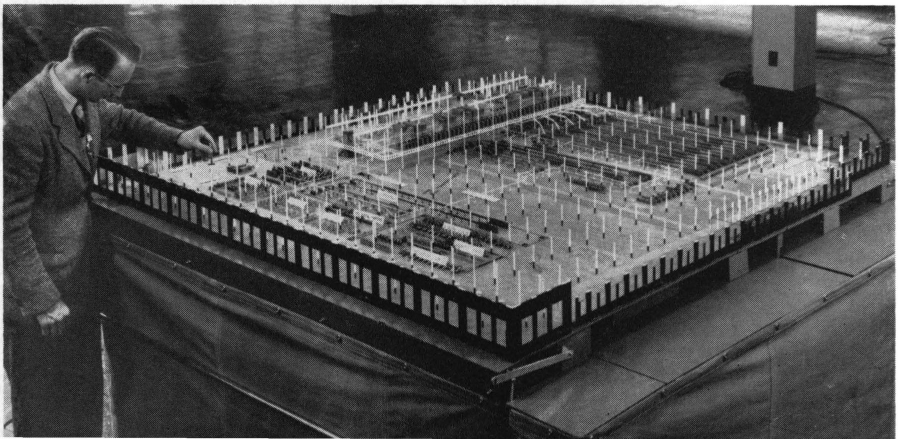
The lowest grade of corporate membership is Associate Member. The requirements are: not less than twenty-one years of age; a graduate of an approved engineering curriclum, or equivalent attainments, including five years of increasingly important engineering experience indicative of growth in engineering competence and achievement: either an electrical engineer by profession or a teacher of electrical engineering subjects. There is also a grade of Student Member. The institute has established student branches in many of the engineering colleges of the United States.

INDUSTRIAL ENGINEERING

Industrial engineering is a relatively new professional field, whose development has paralleled the growth of the machine age. It may be defined as the branch of engineering which plans for the actual manufacturing of the products of industry. It also includes design of the machines and the selection of the machines that are to be used in the manufacturing operations. The slogan of the industrial engineer might be: Obtain the best economy in the use of men, machines, materials, and money. He is the man with the "know-how" who can bring men and machines and materials together, use the machines and materials most efficiently, and give the men the most benefits for their contribution to production.

In the industrial engineering curriculum advanced technical courses, particularly in the area of design, are replaced by a group of courses that deal with the management of materials, men, and money. These include such courses as Safety Engineering, Engineering Economy, Personnel Supervision, Job Evaluation, Time and Motion Study, General Accounting.

This is a cutaway scale model of a proposed manufacturing plant. The industrial engineer is arranging models of machines and equipment to give the most effective production when the plant is built. (Courtesy Western Electric Co.)



Fields of Industrial Engineering

There are several fields that might be listed as areas of specialization for the industrial engineer. These are time and motion study, methods study, cost control, quality control, production planning.

Time and Motion Study. The industrial engineer employed in time and motion study observes the operations of men and machines with or without the aid of motion pictures. He uses this information as an aid in establishing incentive wages, to improve the scheduling (order in which work is done), and to obtain information about costs.

Methods Study. The engineer engaged in methods study may use some of the time and motion study techniques, but his emphasis and major study are on the machines. He makes constant studies to develop better methods for handling materials.

Cost Control is an effective tool of factory management. It seeks to eliminate waste and unnecessary usage of materials and labor, and to obtain maximum production through the analysis and effective coordination of the various activities of the company. The cost control operation is applied to equipment repairs and maintenance as well as to production line operations.

Quality Control calls for continuous checks of the production procedures to make sure that qualities such as weight, thickness, color, taste, hardness, strength, and durability meet the specifications. This calls for the use of modern devices such as spectrographic and X-ray equipment, electronic machines, optical tools, and various pieces of apparatus for making chemical analyses.

Production Planning. The industrial engineer who engages in production planning needs a thorough knowledge of his plant's capacity to do work. He must make sure that the raw and partly finished materials are in the right place, in proper amounts, at the right time. Also, he must have the right machines, in proper sequence, in sufficient quantity, with enough power to operate them. Similarly, there must be enough men, with the required skills, to operate the machines.

Characteristics of Industrial Engineers

Qualifying or distinguishing characteristics of an industrial engineer are that he should (1) enjoy working with people and have a knack for directing them, (2) have the ability to visualize, that will enable him to select machines and plan their use, (3) have the ability to express himself clearly both in the written and spoken form, (4) have many of the qualities of a successful salesman.

Professional Organization for Industrial Engineers

The American Institute of Industrial Engineers is the professional organization for industrial engineers. It is one of the newest members of Engineers Joint Council and is represented on all EJC Committees. Its organization is similar to that of the founder societies. Its monthly publication is the Journal of Industrial Engineering.

The lowest corporate grade of membership is Associate Member for which the requirements are: B.S. in Industrial Engineering and three years of engineering experience.

The institute has established student chapters in ECPD accredited schools.

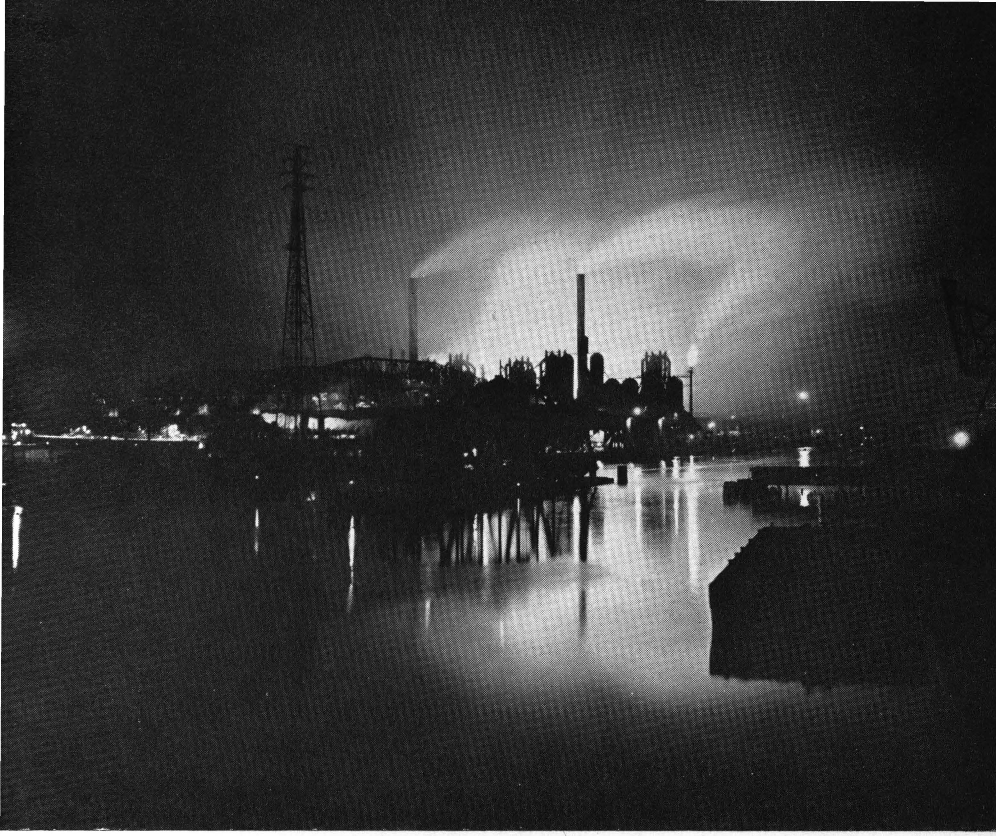
MECHANICAL ENGINEERING

Mechanical engineering underlies every type of engineering where a manufactured product is involved. Furthermore, its operations are basic in transforming energy from its simple state, such as coal or oil, into usable energy. In its strictest sense it relates to the engineering of machines. Actually it includes all industrial activities from extremely fine watchmaking and instrument design to such large operations as locomotive-building and the design and operation of power plants.

Although these machines and devices are new, the principles upon which they operate are very old. The energy from a running stream of water was applied to the grinding of corn long before the Christian Era. The elements of the atmospheric engine were included in an ingenious device for opening temple doors. This was described by Hero of Alexandria about 200 B.C., but the atmospheric engine was not devised until 1712 by the Marquis of Worcester. James Watt developed this into a steam engine about 1774. This same Hero described a piece of apparatus resembling a reaction wheel, but there was no successful reaction turbine until Parsons built one in 1884.

There are similar examples in other branches of mechanical engineering, all showing how recent our industrial development is. The first internal combustion engine was built in 1675 and used gunpowder as a fuel. Mechanical refrigeration had practical application in 1755, in the construction of a vacuum machine which facilitated the freezing of water by evaporation.

The most recent and startling developments are atomic power and the jet engine. Both will have significant industrial applications to peace-time uses, although their military uses are best known now.



This night picture of a steel mill epitomizes manufacturing, which is the work of the mechanical engineer. Power is produced from the gas that comes from the huge blast furnaces, where mixtures of coke, slag, and iron ore are turned into molten metal. Power is used to operate the huge machines that shape this molten metal.

Fields and Occupations of Mechanical Engineers

The American Society of Mechanical Engineers has a number of technical divisions. These are: Aeronautics, Applied Mechanics, Fuels, Graphic Arts, Hydraulics, Iron and Steel, Machine Shop Practice, Management, Materials Handling, Oil and Gas Power, Petroleum, Power, Process Industries, Railroad, Textile, Wood Industries.

Mechanical engineering, as with many of the major professional areas of engineering, has several fields of specialization. Among these are: aircraft; automotive; heat-power; heating, ventilating, air conditioning; industrial; metallurgy; machine design. Many engineering schools offer optional courses in these special fields to seniors and graduate students.

Aircraft includes the research, development, design, and manufacture of power plants and accessories for all types of flying machines. The engine is changing from one that is rotating and internal combustion to a gas turbine, jet-propelled type. Temperatures are very high in the combustion chambers of these newer type engines and there are many difficult metallurgical problems.

Automotive, as we will consider it here, covers the research, development, and design of power plants for various types of self-propelled vehicles. This would include automobiles and trucks, diesel-electric locomotives, tractors and power machinery. Generally, this category has meant engines of the internal-combustion type, and has not included steam engines. This is a very large field that touches almost every aspect of our lives. Engineers who succeed in it need a good deal of ability, courage, and resourcefulness.

Heat-Power deals with the production of power from coal, oil, or gas (usually). Engineers in this field design, install, and operate boilers, turbines, coal and ash handling equipment, feed water purifiers, condensers, and all sorts of gauges and regulating devices. The steam engine is still a very useful and important source of power, particularly in large stationary plants where steam is used to run electric generators or to furnish heat for buildings.

Heating, Ventilation, Air Conditioning includes the design and manufacture, sale, installation, and service of equipment in homes, industrial and commercial buildings, offices, warehouses, and transportation units. It is a rapidly expanding field that is receiving much attention and advertising. The reader should remember that we are considering the work which an *engineer* does in this field. Many people have unwittingly confused the work of the engineer with that of the mechanic who installs, repairs, and services the equipment. The latter is a very important and necessary man, but he is not an engineer. It is the job of the engineer to design and direct the manufacturing of the equipment so that it will operate when correctly installed by the mechanic.

Industrial covers factory planning and layout, industrial relations, safety, production operations, the management of men, money, and materials. In some engineering colleges it is established as a curriculum. Because of the wide range of abilities needed in this field, a man who is not an engineer may do many phases of the work successfully.

Metallurgy requires a good knowledge of the chemical and physical properties of metals. There is a constant search for new metals, new alloys, or new ways of treating old metals to provide new and needed characteristics. The design of many products is limited by the strength and endurance of the metals that are available for their construction. Some metallurgists are working with metals to provide higher strengths; some are studying brazing and coating methods; others are specializing in welding processes and techniques. Metallurgy is an ever-widening field that calls for men trained in several specialized areas, including mechanical engineering.

Machine Design. Although this is a function and not a field, it represents a very important activity of mechanical engineers and merits special mention here. It covers all kinds of machines from prime movers, such as engines and turbines, to mill machinery, presses, lathes, milling machines, and other machine shop equipment. It ranges from the smallest part of a meter or gauge to the powerful machines that are used for forging or pressing metal. Successful designers of machines need keen analytical and creative ability.

As pointed out earlier, we may have artisans and craftsmen (mechanics), technicians, and engineers working in a factory or office on the same process or product. It may be difficult, in a specific case, to say which acts, manual or mental, are "engineering" and which are not. Each person contributes a necessary and important part. A young man should try to find an operation that fits his aptitudes and interests. It is a mistake and a waste of energy for anyone to try to do things that he is not equipped or prepared to do. There are tremendous opportunities in the various fields of mechanical engineering for many men who are not engineers, and the need for engineers is great.

Characteristics of Mechanical Engineers

The following traits are typical of the mechanical engineer. He should have (1) a liking for machines, mechanical equipment, anything that has "wheels going around." While he need not have above-average skill in the use of his hands — although that would be useful — he should really enjoy the noise and smell of machines and the feeling of grease on his hands. It is important for him to have (2) a better-than-average mechanical aptitude — that is, the ability to visualize objects in various space positions. He should have (3) a leaning toward the practical rather than the theoretical aspects of engineering, with an interest in "making something." His must be (4) a type of mind that thinks about material things, objects, rather than about the abstract.

Professional Organization for Mechanical Engineers

The American Society of Mechanical Engineers is the professional society for mechanical engineers. Its constitution states that its objectives are "to promote the art and science of Mechanical Engineering and allied arts and sciences to encourage original research; to foster engineering; to promote the intercourse of engineers among themselves and with allied technologists; and severally and in cooperation with other engineering and technical societies for broadening the usefulness of the engineering profession."

The beginning grade of corporate membership is Junior Member for which the requirements are: sufficient engineering experience to enable the candidate to fill a subordinate position in engineering work or a graduate of an engineering school of accepted standing; twenty-one years of age.

The society has established student branches in most of the engineering colleges of the United States. These student members are regarded as student associates of the American Society of Mechanical Engineers. They have opportunity to cooperate in many of the society's activities.

MINING AND METALLURGICAL ENGINEERING

Mining and metallurgy are associated in the name of their founder society. They are closely related in actual field operations, particularly in the mining of metals, but they differ in the manipulations. Generally, there are separate curriculums for mining and metallurgical engineering.

Fields and Occupations of Mining Engineers

The mining engineer extracts minerals from the earth and prepares them for the market. These minerals are commonly divided into three general groups: (1) metallic minerals, from which are extracted such metals as copper, iron, lead, zinc, gold, silver, and recently, uranium and thorium; (2) nonmetallic minerals, such as fluorspar, limestone, asbestos, sand, gravel, crushed stone, and clay; (3) fuels, such as coal, petroleum, and natural gas.

Exploration. The mining engineer requires a wide range of education because his work involves phases of several other kinds of engineering, such as civil, electrical, and mechanical, plus the science of geology. He must have a knowledge of the latter to enable him to locate ore-bearing strata, petroleum deposits, coal deposits, and other minerals. And he must be prepared to use intricate detector and measuring instruments. Recent advances in the

The mining engineer directs the field work of exploring and sampling a new prospect. Here he is shown mapping the surface geology exposed in the trench. He may stay to construct and operate the mine, or he may move on to a new field.

art and science of prospecting, in which sound waves are used, have taken some of the guesswork out of his job.

Surveying and Mapping. In a large mine the mining engineer would have the help of specialists in other fields — the civil, electrical, and mechanical engineer, and the chemist. But in a small mine he will have to do the work himself. This calls for property line and site surveys and the making of topographic maps. He may have to run surveys to map outcrops where the ore appears at the ground surface, and to locate boundaries of mining claims, or to map underground excavations. He may have to lay railroad track underground, and design and build structures at the mine site, including the power plant, smelters, and washers.

Mine Appraisal means determining the value of mine property and mineral desposits. This is also a duty of the mining engineer.

Assaying is the name for the quantitative analytical process used by the mining engineer in determining the percentage of metal in an ore.

Smelting. After the ore has been removed from the earth, it must undergo processing, usually smelting, to extract the metal which is usually mixed with materials that oftentimes have no use. Sometimes this smelting operation may be done at another site, as is the case with the ore that is mined in northern Minnesota and smelted at Gary, Indiana.

Exhaustion of the higher grade iron ore in the conveniently accessible ranges of northern Minnesota is the principal reason for a new development in the processing of iron ore. Lower grade ores are handled by a special process that removes some of the non-iron-bearing portion. The resulting product has an iron content high enough to warrant shipping to the smelters. This operation is in the field of the mining engineer.

Characteristics of Mining Engineers

The typical mining engineer should have: (1) above-average liking for outdoor work and for some fairly rough living conditions; (2) good health and physical endurance; (3) enjoyment of, and ability in, chemistry and physics; (4) considerable mechanical aptitude and ingenuity that will enable him to make emergency repairs and keep the machinery and plant in operation.

Fields and Occupations of Metallurgical Engineers

The metallurgical engineer takes up where the mining engineer leaves off. Metallurgy is the science that deals with the structure of metals and their alloys, their physical properties, and their thermal and mechanical treatment. A metallurgical engineer must have a good knowledge of physical chemistry. Recent developments in nuclear fission will have profound effects on the study of metal structure.

The mining engineer turns over the material to the metallurgical engineer at the smelter. Here the latter, sometimes designated an Extractive Metallurgist, begins the process of separating metals from the ores, the refining of these metals, and their preparation for use. In the other branch of metallurgy, the Physical Metallurgist deals with the content and structure of pure metals and their alloys. He specifies the methods that are to be used for converting the refined metal into a final product that has certain desired properties, such as strength and hardness. This change may be made by altering the internal structure of the metal through fabrication processes such as casting, rolling, and heat treatment.

Production — the commercial production of raw materials — is one of the fields in which the metallurgical engineer works.

Fabrication and Utilization, another of his fields, has been discussed above.

Research, the third field of the metallurgical engineer, involves studies for the improvement of production, fabrication, or utilization.

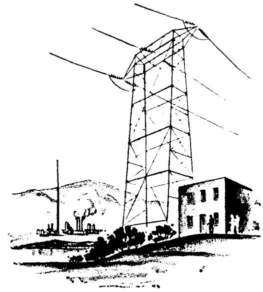
Characteristics of Metallurgical Engineers

The metallurgical engineer should have: (1) high ability in chemistry and physics; (2) some manual dexterity, which he will need in preparing specimens; (3) keen ability to observe, because he will make many physical tests; (4) no aversion or dislike for odors.

Professional Organization for Mining and Metallurgical Engineers

The American Institute of Mining and Metallurgical Engineers is the professional society for mining and metallurgical engineers. Its objectives as set forth in its articles of incorporation are: "To promote the arts and sciences connected with the economic production of the useful minerals and metals, and the welfare of those employed in these industries by all lawful means; to hold meetings for social intercourse and the reading and discussion of technical papers, and to circulate by means of publications among its members the information thus obtained, and to establish and maintain a place for meeting of its members, and a hall for the reading of papers and delivery of addresses, and a library of books relating to subjects cognate to the sciences and arts of mining and metallurgy."

The institute has seven classes of membership, of which Junior is the entering grade. It maintains two types of student relationship. One of these is the individual relationship with a student who pays a two dollar annual fee and is designated Student Associate. The other relationship is with organizations of students at approved schools. They are known as affiliated student societies or student chapters.



chapter 4

The Functional Occupations of the Engineer

WHEN the young engineer begins his work he finds that his assignments are not designated Civil Engineering, Mechanical Engineering, or some other kind of engineering. Instead he hears his employer describing jobs as design, construction, production, and sales. This classification according to function is a very important one. Certain characteristic traits that are peculiar to such functions as design or sales may have more significance than the characterizing traits of a department. For this reason, and because there are similar functional occupations in all of the major departmental fields, we shall devote considerable space to a discussion of these functional occupations.

Research has been variously designated as pure or applied, and there has been a great deal of discussion about it — both as to what constitutes research and the uses that may be made of the results. For our purposes a dictionary definition is adequate: "Studious inquiry; usually, critical and exhaustive investigation or experimentation having for its aim the revision of accepted conclusions, in the light of newly discovered facts."

Research may be carried on in many fields, and the results may appear in a variety of ways. For example, there may result an entirely new product, such as artificial silk or the photoelectric cell; there may be a reduction in production costs, such as we have had in the automobile industry, where there was a continuous improvement in the automobile (a result of research) with a steady decrease in the selling price before World War II; there may be means of utilizing by-products from an already established manufacturing process (this frequently results in new products), such as the tar products that have come from the manufacture of coke; there may be reduced distribution cost as exemplified by the railroads' development of containers that may be loaded bodily on flat cars, then upon arrival at the destination shifted to trucks or to other vehicles; business methods may undergo improvement through research, including accounting practice, billing and collection routine, industrial relations, and others.

Although the basic conceptions of research are very old, the present-day programs of research have had a comparatively recent development, and the great majority of research departments have been organized since the 1920's. Organized research is carried on by five fairly distinct groups of investigators: (1) government institutions such as the United States Bureau of Standards, (2) universities, where the project may be carried on independently or in cooperation with manufacturing companies or industrial associations, (3) industrial companies and industrial associations maintaining skilled staffs and extensive facilities, (4) research institutes operating on a commercial or semicommercial basis, (5) independent investigators working in the line of their regular practice.

Important and essential features of this research are: (1) It is organized and planned. (2) A large percentage has a specific objective, such as a process or a product. (3) Many people are at work on numerous facets of a problem. (4) The workers are usually specialists. (5) Vast sums of money and extensive facilities and other equipment are required.

In the large sense, he who would be most successful in research should possess all of the qualifications that are needed for success in other fields of engineering. There are certain particularly desirable traits. The man should be studious and possess superior mentality, particularly in the sciences. He should have great courage, the ability to apply himself to a problem persistently, and tremendous endurance. He should have some of the spirit of an explorer, because research is a great series of adventures. Like the true adventurer the researcher must be able to endure the hardships that come between the adventures. Analytical ability, ingenuity, and the ability to evaluate the commercial possibilities of research results are all essential attributes.

Design. Webster's New International Dictionary says that to design means "to plan mentally; to conceive of as a whole, completely or in outline . . . to so plan and proportion the parts of a machine or structure that all requirements will be satisfied." Clearly, there are many types of design. Some are new creations, unlike anything that has been done; but the vast majority are built upon the foundation of theory and practice.

Consider the design of a bridge. This involves the selection of a type, the trying of a number of combinations of types and arrangements, with estimates of costs of each to determine which combination of substructure and superstructure will work out most satisfactorily from the standpoint of cost and service. Then the designer proceeds with detailed sketches, drawings, and calculations which determine the sizes, shapes, and lengths of members and the method of attachment to adjacent members.

Take another example: A manufacturing plant needs a piece of apparatus to perform a definite function, that of closing and sealing cartons of soap. The designer might adapt his design from a machine already in use; he might develop it analytically, making careful motion diagrams; he must choose kinds, weights, and shapes of material.

Another type of design is that which requires the assembling of a number of standard pieces of apparatus to form a larger unit. Some of this is mere routine work that requires only a familiarity with the catalogs; others require a thorough understanding of the design and performance records of each piece.

Another phase of design that must have constant attention is the cost. A proposed machine or process of manufacture may be in accord with scientific laws, yet be impractical in a commercial sense.

The work of the design engineer requires that he spend a part of his time at his desk making calculations; a part in the drafting room supervising and checking drawings; and another part in the shop, or in the field, interpreting the requirements of the drawings, or watching tests to learn whether the machine or structure performs as calculated.

A good designing engineer must have a practical as well as a theoretical bent. He must be able to envisage the completed structure in his mind's eye before it is completed. He should have a wide knowlege of materials and their applications, and he should be familiar with factory processes. He should be neat and accurate and reasonably adept at handling mathematics. He is apt to be a poor leader of men because he prefers to work with ideas and things rather than with people.

There is a general belief that design means permanent attachment to a drafting board. It is true that a large portion of a young man's first years in design are apt to be spent at drafting. For this reason drafting skill is an important asset. As for the later years, enough has been said in this brief discussion to show that there is an interesting variety of activities in engineering design. Real design is a challenge to the very highest type of engineering ability, and no man who has the requisite qualifications and interests should avoid design because "he doesn't want to spend all of his life over a drafting board." Those who have this ability, and are able to direct others, will pass on to positions of enlarging opportunity and responsibility where contact with the drafting board will be supervisory only.

Development and Experiment. These are phases of design, but there are some special requirements for success in this field that merit mention. Development is used frequently in combination with other words, such as Sales Development, Process Development, Product Development. There are many activities in engineering that do not lend themselves to purely theoretical planning and design. The piece of equipment, or machine, or a manufacturing process is set up and brought through a succession of stages or states until the desired or a satisfactory condition is reached.

For example, a tractor may have shown some defects in operation. The trouble has been found. The next step is to make the correction. This, or a similar tractor, will be set up in the experimental laboratory of the manufacturer, and the engineers will go to work. By a combination of theoretical and practical application of engineering principles they will arrive at the solution and probably effect an improvement.

Or, consider the problem of adapting rubber tires to farm implements — tractors, plows, cultivators. There are too many uncertain and unknown aspects to permit a theoretical solution. Experimental methods give the answer.

In every manufacturing plant there is constant need and demand for improvement in the performance of machines. As a rule this must be done by experiment, and the new piece of equipment is evolved or developed. Here we find research and development very close to each other.

Another type of development involves the process as well as the apparatus. For example, there is the problem of extracting oil from the soybean. A change in one step of the process entails changes in other steps, all of which requires new or modified equipment. This is the reason for small or "semiworks" plants where difficulties may be ironed out before commercial production is attempted. As soon as the semiworks plant is operating smoothly, the problem of operation on a quantity production basis goes back to the design engineer.

First-rate development and experimental engineers are scarce. They seem to have a sixth sense or intuition that helps them to choose the proper shape or cross sections, or make the right change in design. The financial rewards are large and the work intensely interesting. Skill in that field can probably be acquired. The requirements seem to be ingenuity of a high order, considerable manual skill, a liking for the experimental rather than the analytical method, with a thorough understanding of basic design principles, patience, and persistence.

Construction and Manufacturing. These functions pertain to very different fields, yet the fundamental activities and the basic skills required are similar. The construction engineer supervises the building of factories, skyscrapers, highways, railroads, bridges, dams, water and sewerage systems, power transmission systems, and others. The manufacturing engineer (the more frequent expression is production engineer, which has a narrower meaning, also) has charge of the making of implements and goods. On large construction projects and in large manufacturing establishments the work is subdivided, for convenience, into sections. They have planning departments, cost or estimating departments, and industrial relations departments.

The planning department on a construction project would select the construction equipment; place it on the site; lay out the route to be followed by all materials; make sure that materials were on hand when and where needed. In a manufacturing plant the planning department would arrange the machines on the floor; chart the route of parts during their finishing process, and later, when those parts were to be assembled, make sure that all accessories were on hand when needed.

The cost or estimating department on a construction project must keep accurate records of all costs and be prepared to make estimates that may be submitted on proposals for new projects. For large companies this means a large corps of accountants. In smaller companies one man, frequently the engineer, must be a sort of Jack-of-all-trades. A manufacturing plant has a very comprehensive cost department because its selling prices must be based upon costs. Frequently, the section which makes time studies and sets rates on piecework is associated with the cost department.

Relations with employees are handled through a separate department, often called Industrial Relations Department. Here all matters of wages, safety, health, disability, and pensions are discussed freely by manager and worker.

Any engineer who chooses to follow construction or manufacturing and hopes to rise to a position of responsibility must become familiar with all phases of the work. The following traits are important: ability to get along with and direct other men; a keen sense of costs and efficiency in handling materials and men which will enable him to carry on his work most economically and efficiently; promptness in arriving at decisions, because there are times during construction or in a manufacturing plant when very important decisions must be made without delay; good health and a good physique, because most construction is out of doors and the hours are long, and manufacturing requires long hours, sometimes with heavy work.

Sales, Service, Application. Goods are manufactured to be sold at a profit. The same is true of services. Engineering equipment and services require engineers for the selling. To be a good sales engineer requires high-grade technical ability plus the personality traits that are needed by all men who make public contacts. Their work is not mere "doorbell ringing."

A few examples will help to make this clearer. Meters and gauges, used in all power plants, are very intricate devices. Companies which manufacture them have learned that they must be installed under the direction of an experienced engineer, called a Service Engineer. This man gains the confidence and good will of men in the plant and secures orders for new equipment.

There are many complex problems in the lubrication field. Large oil companies are giving young engineers special training courses in what they call Lubrication Engineering. These engineers will call on industrial companies, help them with their problems, and perhaps sell some lubricants.

Manufacturers of building materials, such as sash, insulating materials, wallboard, plaster, blocks, lath, trim, and others, have organized large staffs of Sales Engineers. These men call on clients, either dealers or the actual users. In the case of a user they will look over his problem, make measurements, and suggest a plan for the proposed improvement. In some instances where special skill is needed, they may return to make the installation, after making the sale.

There are many instances where one piece of equipment must be adapted for use with another piece of equipment. The following are examples: electric motors and gasoline engines to operate pumps and compressors; electric welding in the assembly of a steel structure; photoelectric cells as selecting or counting devices. Men who handle such assignments are known as Application Engineers.

A sales engineer in addition to being a good engineer must understand people and enjoy working with them. He must have tact, patience, perseverance, and good judgment; he must be able to gain and hold the attention and interest of his customer without irritation; he must know when and how to close a deal. Above all, he should have the knack of making people like and trust him, so that they will be glad to have him call, and when they need some help or advice they will think of him.

Operations. This might be included under manufacturing. The word is used frequently and deserves brief mention, however. The man in charge of operations — superintendent, plant manager — is responsible for the efficient planning, organization, and execution of the coordinated activity of men, money, and materials under his direction. He must have a personality which commands loyalty and respect. He must organize and correlate the men and work so that each man is doing that for which he is best fitted, at the same time avoiding ill feeling and friction.

He must have a broad understanding of all of the detailed work in his plant, although he would not be expected to know every detail, such as the operation of each machine, because that would be left to his foreman. But he must be able to say when his men are performing satisfactorily.

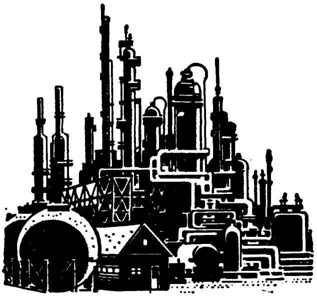
In the past most of the men in charge of operations have come up through the manufacturing departments — practical men. Many large companies are now offering engineering graduates opportunities to work into operating positions. The beginning work is hard and arduous and the hours long, but the rewards for those who make good are large.

GRADUATE STUDY AND SPECIALIZED EDUCATION

The expanding fields of science and technology, brought about by advanced mathematical and scientific studies and the development of new materials and new processes, pose a dilemma for young people who are planning careers. On the one hand we see the clear need for more men and women with advanced scientific and technical training to deal with the complex problems of our technological civilization. Some authorities maintain that the survival of our western way of life is in danger if our output of scientifically and technically educated personnel does not keep up with that of the communist countries. On the other hand we see the equally clear proposition that the world needs an increasing number of people whose education is broad enough and basic enough to enable them to deal with life's complex problems. The crux of the dilemma seems to lie in the fact that very few people are competent in both areas. Therefore, when choosing what to do, many may follow only one of the routes.

All of this is important to the high-scholarship graduate from any engineering curriculum who considers advanced study or graduate work. Some may choose, as a few have done, to make specialized preparation for careers in a field such as business, law, or administration. However, the majority will follow lines of specialized study in science and engineering. There are expanding opportunities and increasing demands for men with educations beyond the bachelor's degree. Employers are paying more than the normal beginning salary to men who have earned advanced degrees. Moreover, with other conditions equal, a man with an advanced degree should move ahead of the four-year-degree man in salary and responsibility.

Many industries, foundations, individuals, and public agencies are encouraging able young people to go on with graduate and research studies. They do this by paying the student sums of money, frequently designated *scholarships*, that he may use to pay portions, sometimes all, of the cost of his graduate education. Some of these grants are designated for study in named areas. For example, a very important field is that of Nuclear Energy. Here, the Atomic Energy Commission and some nongovernmental agencies are offering scholarships that may be used for advanced study in science or in applications (engineering). Generally, this study includes course work and research on a project, named a thesis, and culminates after a year's full-time study in a Master's degree, and after three years' full-time study in a doctor of philosophy or doctor of science degree. The bearer of one of these degrees will find an increasing number of attractive opportunities. In fact there are some positions, such as those in engineering college teaching or research, where an advanced degree is almost a "must."



chapter 5

Industries That Employ Engineers

IN THE discussion which follows we shall present a very brief outline of the opportunities that are available for engineers in a number of industries. Any attempt to offer detailed information about any or all of these would call for a volume much beyond the aim of this booklet. It is the author's hope that these outlines will serve as guides and suggestions to the reader who is seeking a picture of the scope of engineering. The reader can fill in the details if he will read descriptive books and pamphlets that are written for that purpose. Some of this interesting and informative material may be obtained from the companies who employ young engineers. Recently those companies have been preparing pamphlets and brochures which describe the work and opportunities that engineers may find with them. In most instances they would welcome inquiries from young men who are seeking information.

It should be pointed out, too, that the list of companies or industries chosen for inclusion in this book is by no means complete. Nor is the arrangement or grouping based upon a strict system. For example, radio and telephone might have been combined under the general heading communications. The author believes that the fields included are important. Furthermore, they are grouped so that they will be recognized readily by the reader.

AUTOMOBILE INDUSTRY

This is an alert, aggressive, dynamic, sales-minded, and highly competitive industry. It has had a phenomenal growth which has affected many segments of our economy. Actually it is an industry of many parts, each of which is large. There are engine-manufacturing plants, body plants, frame plants, generator plants, axle plants, radiator plants, and many others. All of these are brought together in an assembly line operation that is one of the remarkable developments of the American automobile manufacturers. Several other manufacturers have copied this technique.

The work is specialized. In fact, several of the automobile companies carry on their own educational programs at both the college and the trade school level. Most college men who enter the automobile industry do so by way of one of these training programs. One company has an advanced program which they designate as a graduate engineering course.

The industry has use for all kinds of engineers because the manufacturing companies have very diversified activities on a very large scale. Probably the need would be greatest for mechanical, metallurgical, industrial, and electrical engineers, with a lesser need for chemical, ceramic, and civil engineers. From the functional standpoint the industry uses design, development, research, production, plant, construction, sales engineers, and others.

AVIATION

The aviation industry offers opportunities to aeronautical, mechanical, electrical, civil, chemical, and other engineers in the design and manufacture of the airplane and its accessories, in the construction, operation, and maintenance of airports and landing fields, in the operation and testing of airplanes, in research and teaching, and in governmental employment.

In manufacture there is the design of the plane structure, which is a problem in stress analysis and the selection of parts. Much of this work is routine drafting, but there are opportunities to rise above the drafting board.

The design, production, and testing of the engines offer a field for all types of ability from the routine draftsman to the most creative genius. Much of the work must be experimental, so there are many places, both training and permanent, in this field.

World War II gave tremendous impetus to research and development. The federal government is spending billions of dollars on plants, equipment, and men, for wind tunnels, supersonic research, rockets, and others. The need is for engineers and physicists with keen research and development ability.

The construction and operation of airports require the services of engineers who have had experience in such work. Of course, there are many staff jobs involving schedule and tariff-making, accounting and auditing, and others, which may be handled by nonengineers. Many of the airline companies are placing their retired pilots in some of these executive and operating positions.

Perhaps a technical education will become an important qualification for pilots because of the increasing number of intricate mechanical features of the airplane, which the pilot must understand. It is probable that the trend will be toward increasing emphasis on educational qualifications. When a college degree becomes an important prerequisite, a man with an engineering degree would have that as a "plus" qualification.

CHEMICAL INDUSTRY

This is a very large, much diversified, and rapidly growing industry. It could be classified into subgroups such as heavy chemicals, light chemicals, and organic chemicals. Probably the most satisfactory way for us will be to make the classification according to important groups of products.

Generally this is the field for chemical engineers, with some demand for mechanical engineers, and less for civil or electrical engineers. They find work, usually, in the following functional departments: Engineering, Development, Research, and Manufacturing.

Engineering in many chemical companies includes the following: Design, which means the design of new plants and plant additions, changes in layouts, and equipment; Construction, where estimates are prepared, contracts made, field work supervised; Industrial Engineering, where the main objective is to lower cost of production and improve quality of products.

In the **Development Department,** patents and processes are evaluated from a commercial point of view, and trends in certain lines of manufacture are analyzed.

The importance of **Research** to the chemical industry is well known. Millions of dollars are spent annually in a search for new products and for new uses for old products. Some engineers enter research.

In the **Manufacturing Department** most of the engineering graduates will be engaged in production work, that is, in the actual processes of turning out the company's product. Mechanical engineers will find opportunities here in design, power, maintenance, and construction.

As mentioned previously, entire industries have been built around individual products in the chemical field. Some of these include: ammonia, where fertilizers, antifreeze, high alcohols, some resins, etc., are made; explosives, including glycerine, nitroglycerin, and gunpowder; fabrics and finishes, which include artificial leather and lacquered fabrics, enamels, solvents, etc.; pigments that are used in paint, lacquer, linoleum, rubber, inks, paper, soap, textiles, etc.; plastics, where many shapes and sizes are molded from sheets, rods, and tubes; rayon, from which yarn, film, caps, and bottle closures are made; chemicals, inorganic and organic, such as insecticides, dyestuffs, and ethyl alcohol.

CONSTRUCTION INDUSTRY

The construction industry is second in size to agriculture. We include in the industry, although not directly involved in actual construction projects, the mines, mills, and factories that produce the materials such as cement, glass, sand and gravel, and brick, and the heating and plumbing systems, elevators, electrical and power systems, and other equipment and apparatus. Men who work in it include those who conceive and design, those who build with their own hands, and those who own the business. These men build thousands of structures ranging from farm buildings to water and sewage works, highways, skyscrapers that cover a city block, long bridges, and high dams. There will be continuing and increasing need for such men because there is more and more demand for projects that produce power, flood control and irrigation, also national and regional highway systems and toll roads, city planning projects, airports, industrial plants, and homes.

All of this will mean an increaesd demand for engineers in the construction industry. A civil engineer would begin work on these jobs as a timekeeper, instrumentman, or assistant estimator, or he might, if granted permission by the labor union officials, serve as a common or semiskilled laborer to learn construction operations firsthand. As he gained experience, the civil engineer would advance, in the office, to estimator or office engineer; in the field, to construction superintendent. Mechanical and electrical engineers would be responsible for the proper use and maintenance of equipment and the applications of power, on the job.

ELECTRICAL MANUFACTURING

This large industry employs approximately one-fourth of the engineering graduates of our colleges each year. It includes, in its broadest phases, some of the industries which we are listing separately in this discussion. Some of the principal divisions are appliances, automotive electrical equipment, radio and television, electrical controls, computers, business machines, transmission supplies, wire and cable, and generation equipment. Except for appliances (toasters, washing machines, sweepers) the products of this industry are for use by other industries. Therefore, there must be close cooperation in the planning, design, and manufacture of the equipment. These and other problems require many engineers. As a result, engineers make up a large percentage of the total number of employees of the industry.

Probably the largest number of these will be electrical engineers, although mechanical engineers will be a close second, followed by industrial and chemical, with a few ceramic engineers. The design of electrical equipment has both electrical and mechanical engineering problems. These involve stress, heat flow, vibration, friction, dynamics, and many others. Furthermore, the need for close cooperation between the manufacturer and the user of a piece of equipment makes it necessary that there be engineers, called application engineers, skilled in this field. Also, there is a demand for many sales engineers. Research, too, in many phases of the industry has kept it in the forefront both in people's thinking and in the up-to-dateness of its products.

ELECTRICAL UTILITY

The electric utility companies have always employed large numbers of engineers. In the main, these have been civil, electrical, industrial, and mechanical engineers. The work includes engineering, construction, testing, operating, sales, and service, which are necessary in the production, transmission, and distribution of electrical energy.

Engineering involves drafting and design in connection with the planning of equipment and line additions and improvements.

Construction includes surveying, line construction, and equipment installation.

Testing refers to line, equipment, and material testing. Electricity is an essential and useful form of energy when properly handled, but all possible safeguards must be provided to prevent accidents. Testing helps to provide those safeguards.

Operating deals with the production and transmission of the electrical energy. It is produced in generating plants which may be actuated by water or by some form of fuel engine and, soon, by nuclear energy. This is a very important and little publicized phase of the work. Transmission includes studies of tie lines, power flow, high tension terminals and sub-stations, and distribution systems for alternating and direct current.

Sales and **Service** have assumed increasing importance in recent years, as the number of uses for electricity has increased. Utility companies employ sales engineers who are charged with the job of helping the customer to solve his problems electrically.

FOOD TECHNOLOGY AND MANUFACTURING

Engineers are prone to omit this important industry from their list of employment opportunities. In a general way it is well known because of its aggressive and interesting advertising in the press and over the radio.

Probably a career in this field would be made by a chemical, industrial, or mechanical engineer. At the moment we are thinking primarily of the manuafcturing aspects. In this field there are numerous uses for unit operations for the chemical engineer; for the mechanical engineer there are problems of machine development and design; and for the industrial and the mechanical engineer, problems of production and planning and scheduling, efficiency studies, rate making, safety, and other things that go with factory management.

In other than the manufacturing phases of the food technology field, a man with the typical Bachelor of Science degree in engineering would be handicapped. Here there are highly specialized departments built upon chemistry and bacteriology. The engineer who expects to make progress in this area would be obliged to take many courses in those departments before he would be ready for the work.

PETROLEUM INDUSTRY

This industry offers a wide range of opportunity through all of the functional operations to many kinds of engineers, including in this group chemical, civil, electrical, industrial, mechanical, and mining and metallurgical. A brief outline of the work done will suggest these opportunities to the reader.

There is the phase of surveying and prospecting, locating and marking oil desposits, and determining their potentialities. Civil, electrical, and mining and metallurgical engineers and geologists find work here.

Then there are wells to be driven and operated, pipelines to be laid out, built, and operated. Here is work for civil and mechanical engineers.

In the refinery where the oil and fuels are manufactured there are places for many kinds of engineers: ceramic engineers in the design and installation of refractories; chemical and mining and metallurgical engineers in supervising unit operations and cooperation on design problems; civil engineers in structural design and plant construction; electrical engineers for the design and operation of special electrical equipment; and mechanical engineers in equipment design, plant operation, and maintenance.

After the product has been manufactured there are a host of problems in connection with marketing. Many of these are technical and specialized. Men with sales engineering leanings would do this work. Probably they would come from the chemical, industrial, or mechanical engineering groups.

RADIO AND TELEVISION

There is an immense popular appeal to the fields of radio and television, which has induced many young men to take up the study of electrical engineering. A large percentage of them do not have the necessary aptitudes for the course work of that curriculum. However, both the radio and television industries have large opportunities for the right men. These opportunities will be considered in the fields of manufacturing, communications, and broadcasting.

In **Manufacturing**, electrical engineers will find positions in research, development, and design; also as field engineers, where the work will involve installation and testing of equipment, checking of performance, instructing customers, giving technical aid to the sales department.

Mechanical engineers will work in research, development, design, plant engineering, production engineering, and industrial engineering. Plant engineering involves the generation and distribution of heat, light, and power, and the planning of new plants. Industrial engineering involves cost control, making time studies, and motion economy. Production engineering means supervision of manufacturing processes.

In **Communication** and **Broadcasting**, electrical and mechanical engineers will find work in research, design, installation, testing, and operation of all types of equipment. Specific fields include transmission, reception, electroacoustics (conversion of sound to radio wave and vice versa), and television. These various branches are so closely related, in research, design, manufacturing, and operation, that the large broadcasting companies, networks, and manufacturers find it desirable and necessary to engage in all of the activities.

Many of these jobs require skilled operators and technicians, men who have come up through the manually skilled route. As the technical problems increase in complexity there is a growing tendency to replace the artisan-trained men with those who have an engineering college training. It follows that the engineers who go into this type of work will find it advantageous if they have some manual skill.

RAILWAY ENGINEERING

Civil, electrical, and mechanical engineers will predominate here. Civil engineers find work in the field on surveys, construction, and maintenance, and in the office on drafting and design for track and structures.

Electrical engineers do the design, operation, and maintenance of the electrical equipment. This includes electrical problems of the motor-driven locomotives, the signal equipment, and others.

Mechanical engineers take care of the design, operation, and maintenance of the motive power.

Opportunities in the railway field are more numerous than one might think. Railway management is showing an increased interest in young engineers. Some day these young men will occupy important executive positions. The way to the top is slow and hard and is beset with much tradition. After all, railroading is a specialty, and no young man should feel that his engineering college degree will admit him to the fraternity without first proving his worth.

Another aspect of this railroad field is the manufacturing of railroad equipment. This includes locomotives, cars, track, terminals, and other equipment. Engineering opportunities would be for mechanical, industrial, and electrical engineers in the various manufacturing companies. The scope of the field is large and the need for new ideas and ingenuity very great.

REFRIGERATION AND AIR CONDITIONING

This is an important and growing field, and students of engineering should know about its engineering opportunities. This is particularly important at a time when there is much talk and advertising to encourage young men to enter the field.

In refrigeration the equipment is classified according to size of the machinery as follows: domestic, commercial, industrial. The household refrigerator in its many forms makes up the domestic field. These boxes, either ice or mechanical, are completely engineered and assembled at the factory. Commercial units, which are larger than the domestic units, are also largely standardized; for this reason, most of their engineering would be done during the manufacturing. Industrial applications are extremely varied. Usually they are specially designed and require considerable engineering on the job, such as determining sizes, making plans, and supervising installation.

Air-conditioning units are made in small or package sizes for home installation. The big field has been in the commercial and industrial air conditioning of entire buildings. This demands a high type of engineering on the job because no two problems are the same. Opportunities for mechanical and industrial engineers will be found in manufacturing, in sales engineering, and in the design of refrigerating and air-conditioning systems.

The foregoing does not include various types of service and repair work, of which there may be a great deal, which are not considered to be opportunities for engineers.

RUBBER AND PLASTICS

Manufactured products include tires, boots, wearing apparel, belting, hose, insulation, tank lining, numerous molded rubber goods, synthetic rubber, and many others from rubber. Plastics include some of the rubber items, and numerous products that are also made from metals, such as containers, handles, combs, furniture, utensils, bearings, and others.

The technology of rubber and of plastic is built upon the science of chemistry. However, the design and layout of plant and equipment and the carrying out of the manufacturing process are the work of engineers. Because of the special nature of the products and processes, many of the manufacturing companies have found it desirable to give their young engineers a training course of as much as two years' duration.

In the main, chemical and mechanical engineers are employed, with a sprinkling of electrical and industrial engineers. Chemical engineers take charge of the compounding and processing of the products. Mechanical engineers are responsible for mold and machine design and plant operation and maintenance. Electrical engineers design electrical equipment. Industrial engineers see that efficient and profitable operations are maintained.

STEEL INDUSTRY, INCLUDING MANUFACTURING AND FABRICATION

This industry starts with the gathering of the raw materials — ore, coal, and limestone — and passes through successive processes of transformation into useful steel and iron products, including their fabrication into finished structures and machines. It employs a large number of engineers each year. In considering the opportunities, we shall find it helpful to list the work done by each type of engineer.

Architectural engineers find work in the planning and design of buildings and the supervision of their construction.

Ceramic engineers are employed principally in the design, selection, and adaptation of refractory materials to the furnaces. These are linings which protect the steel frames from intense heat. Another field is that of abrasives, which are used for sharpening, grinding, and polishing. The ceramic engineer's part in applying protective coatings to steel products is growing in importance.

Chemical engineers find their largest field in connection with the design and operation of the apparatus used in the utilization of the by-products, such as coke-oven gases and coal-tar. They, with the mining and metallurgical engineers, also supervise the making of chemical and steel analyses, combustion tests, and others. They work with the ceramic engineer in the application of protective coatings on steel products to prevent rust and corrosion.

Civil engineers are engaged in the layout and construction of the plant, its utilities, equipment, roads, and their maintenance and operation after construction. They also do the planning, designing, and erecting of the buildings, bridges, and the like, that are built from steel shapes.

Electrical engineers are engaged in the generation, distribution, and application of electric power in the mill. A modern mill depends almost entirely upon electrical power. Its distribution system is very similar to that of a small city. The electrical engineer designs and lays out this system, then builds and operates it.

The industrial engineer has the broad problem of seeing that the plant is run in a businesslike and efficient way. He studies machinery and plant layout and recommends changes; he correlates time and motion studies and wage systems; he makes cost estimates and determines the probable return from new products.

The mechanical engineer's principal work is in the design, construction, and operation of mill machinery and material-handling apparatus. Details include determination of roll size and contour, rolling pressures, speeds, runout tables, conveyor, cranes; also, the design of furnaces and convertors. Many mechanical engineers work into operating positions of responsibility, leading to that of superintendent and works manager. Others are responsible for plant and equipment maintenance.

Mining and metallurgical engineers have the important task of testing and determining the quality of the steel during its manufacture.

TELEPHONE INDUSTRY

Engineering work in this industry will be done largely by electrical, industrial, and mechanical engineers in three broad fields, namely, technical operations, engineering planning, and engineering development and research.

Technical Operations are found mainly in the plant departments of the operating telephone companies and in the manufacturing and installation departments of the maufacturing company.

In the operating companies the engineers will have charge of skilled workmen in three departments. These are: Engineering, where buildings, office equipment, and transmission systems are planned; Plant, where plans are made and carried out for extension of the outside plant, exchange installation, and property maintenance; Traffic, which operates the switchboards that give service to the public.

In manufacturing, the engineers will be in charge of groups of men in a factory where many diverse and highly technical processes are in use.

Engineering Planning involves the construction and maintenance of the telephone plant, the manufacture of apparatus, and the installation of central office equipment. It includes the development of plans and methods by which suitable technical standards may be met in the most satisfactory and economical way.

Engineering Development and Research are usually carried on in laboratories which are arranged for that purpose. Here, engineers make a critical study of the telephone plant and its operating conditions, formulate the requirements to be met, and devise means for accomplishing the desired result. This work is highly technical and involves research in chemistry, magnetism, physics, optics, mathematics, and their numerous applications.

FEDERAL DEPARTMENTS

In the following outline we shall name some of the governmental agencies that employ engineers. Most of these positions are obtained through civil service examinations. The number of engineers in the government service has been growing steadily, and the end is not in sight. This employment offers reasonable security and an opportunity for individual growth.

Bureau of Reclamation employs civil, electrical, and mechanical engineers for surveys, design, and supervision of construction of dams, spillways, and other structures required in the federal land reclamation and power development program.

Bureau of Standards employs all types of engineers with research aptitudes.

Civil Aeronautics Administration employs civil, electrical, and mechanical engineers to supervise construction and operation of airports, airways, and airplanes.

Coast and Geodetic Survey employs civil and electrical engineers for triangulation, leveling, mapping, and hydrographic surveying.

Engineer Department employs civil engineers who work on the improvement of rivers and harbors.

Geological Survey employs civil engineers who make topographic surveys and gauge streams.

Interstate Commerce Commission employs civil, electrical, and mechanical engineers who make necessary studies and assist in regulation of transportation agencies.

Office of Supervising Architect employs architectural, civil, electrical, and mechanical engineers who act as inspectors and supervisors of construction on federal buildings.

Bureau of Public Roads employs civil engineers who cooperate with state highway engineers in the building of federal aid highways, and construct roads in national parks.

Soil Conservation Service employs agricultural and civil engineers for design and construction of soil-saving structures.

Bureau of Mines employs mining and metallurgical engineers on surveys and inspection.

STATE DEPARTMENTS

Highway departments employ civil engineers who plan, design, construct, and maintain state highways.

Sanitary Engineering departments employ civil engineers who supervise the design and construction of sewage and water works, regulate uses of streams, and participate in general sanitation an public health problems.

Building Inspection departments employ architectural, civil, electrical, and mechanical engineers for inspection and supervision of construction of public and other buildings.

COUNTY AND CITY DEPARTMENTS

Civil engineers are employed by counties in connection with the planning, construction, and maintenance of roads and bridges. Large cities employ architectural, civil, electrical, and mechanical engineers to design, construct, and maintain streets, water supply, and sewerage systems, bridges and buildings, power plants, and others.

chapter 6

Factors That Determine Success

AT THIS point we need to give specific attention to the factors that will affect one's success in engineering, both in college and after graduation. In our preceding discussions we have emphasized the importance of aptitude, interest, industry, and personality. Now we will talk about success, to see what it is, how it may be measured, and what each man may do, or avoid doing, to achieve it.

HIGH SCHOOL PREPARATION

The foundation for a successful four years in the engineering college is laid in high school. This consists, in part, of adequate and effective preparation in mathematics and the sciences. These have been described in Chapter 2 where we have discussed aptitudes and interests. Because this preparation for an engineering career does begin in high school, it is important that the prospective engineering student shall have rigorous and adequate discipline in his high school mathematics and science courses. If he has that type of "conditioning" in his high school courses he will be reasonably well prepared for the demands of an engineering curriculum. Some of the engineering colleges require an applicant to pass an entrance examination before he may be admitted. The typical requirement for his unrestricted admission is graduation from an accredited high school where his program shall have included the following subjects:

Subject	Units
English	3
Social Studies	1

Algebra	1½
Plane Geometry	1
Physics or Chemistry	1
Science	1
Additional work in above subjects	3
Other subjects	3½
Total	15

SUCCESS IN COLLEGE

Those who pursue an engineering curriculum will encounter many interesting experiences. There are hazards, too. Between forty and fifty per cent of those who begin engineering will complete the program and receive a bachelor's degree. Approximately one-third of those who fail to finish have scholastic troubles; the other two-thirds fail because of lack of interest, finances, health, conduct, marriage, and other personal reasons.

We will look at the causes of scholastic failures. One-half of them are chargeable to lack of ability and lack of interest; one-sixth to poor preparation; the remaining one-third to a group of causes, including lack of effort, too much time for self support, too much time on extraneous (sometimes extra-curricular) activities, health, and entrance conditions.

The significant lesson that a prospective engineering student may learn from these figures is that he should do his best to estimate his ability and interest before he begins an engineering curriculum. It is probable that a large percentage of those who failed to graduate in engineering because of lack of ability could have graduated in another curriculum for which they did have the aptitude and interest. These failures to graduate represent loss of a substantial amount of time and money as well as disappointment to the student. Perhaps he made an equivalent gain from the courses which he did complete, but he could have had more for his money in the proper curriculum.

A few students will fail in spite of their best efforts. Many fail because they lack the ability to adjust themselves to a new type of living. They need training in character development and need the will-to-do. The man who is ready for college is prepared for his college studies and for college *life*. He who would be successful in college and later must do these things: (1) make his own decisions; (2) steer his own course; (3) do his own thinking; (4) accept his responsibilities; (5) perform his daily duties promptly and regularly without having someone remind, urge, or order him.

Earning One's Way. Too much outside work in trying to earn their way while attending college has paved the way for the downfall of many earnest and well-meaning college students. It is creditable to earn one's way while at college. But carrying a normal engineering schedule is a man-sized job which requires approximately fifty hours per week — thirty in classroom and twenty at the study table. An excessive expense-earning program is apt to result in (1) inadequate class preparation, leading to low scholarship, which may bring a low quality point average and deferred graduation; (2) overwork; (3) no opportunity to participate in college life. So, in the end, the attempt to do too much may bring a "below-average" scholarship record or injured health, neither of which is necessary if one uses good judgment in planning his work program. The secret is moderation in all things.

It is well known that many college students fail during their first year because they neglect their studies. Some of these are the unwitting victims of their own inexperience. Others follow bad examples of older students who are "getting by." The engineering college is *different* from high school. The standards of performance are higher and more exacting and the amount of work (studying) is much greater. Yet that college work is not too difficult for those who are well prepared, industrious, apt, and systematic in their studying. The man who cannot determine when he shall study, what he shall study, and how he shall study will waste many precious hours. That is the reason for the following section, "How To Study."

HOW TO STUDY

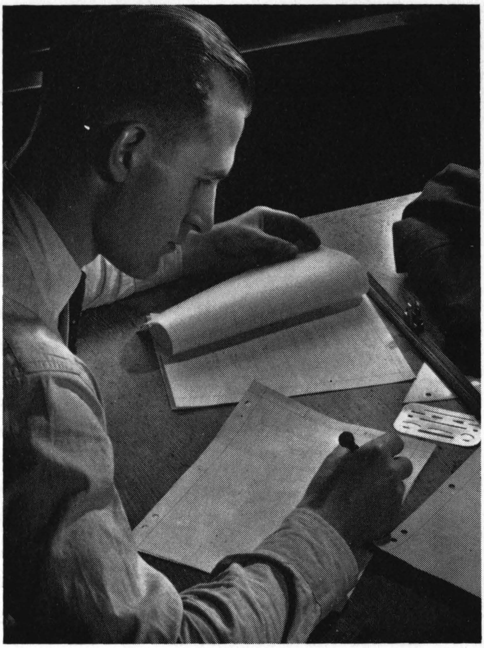
Good study habits are important because the study not only brings information for use at the moment but it also brings *mental habits,* which are likely to be *more lasting* than the information itself. The *right mental habits* are particularly important to an engineer because the study of engineering is intensive and aims at a mastery of fundamentals, the development of a point of view, and a systematic way of solving problems.

Physical Conditions of Study

1. The room should be clean, in good order, well ventilated, and at a comfortable temperature — not too warm.

2. Chair and table should be at the proper height for the individual. In general, study may be done best at a study table. Sitting in an easy or lounging chair usually leads to drowsiness and lazy thinking.

3. The student should be comfortably dressed for the night's study. Although brief and intensive study periods between classes



The engineering student and the practicing engineer have to make many calculations. This calls for good mathematical ability, the capacity to analyze and create, accuracy, and persistence.

are valuable, the engineering student will find that his most effective studying is done in his room after he has eaten a moderate evening meal.

4. The light should have the proper intensity and should be properly located. It should come to the student's book or paper so that there will be no shadows on his work. The purchase of a study lamp will prove a good investment.

5. Equipment should be good. Everything should be at hand and in good shape before study begins. Dull pencils, balky fountain pens, and inaccurate scales and slide rules are annoying and often are the cause of poor and incorrect work.

6. Avoid studying when fatigued, either mentally or physically. After a couple of hours of intensive study a few setting-up exercises or a walk around the block may help to regain the "second wind." Some students prefer to do all of their studying before going to bed; others prefer to rise early and study before breakfast.

7. In regard to conversation, remember that there is a time and place for everything. Some of the most pleasant memories of college are oftentimes associated with the gatherings in study rooms (familiarly known as "bull sessions"). But they can become most prodigal wasters of time. There is always a group of students who seem to have little studying to do, and others who are looking for excuses to defer studying. Frequently, these men make nuisances of themselves when they gather in the convenient rooms of men

who would like to study. This is a form of robbery, because they are stealing the precious study time of men who wish to work.

Study Aids

There are four aids that may be helpful in directing and concentrating one's attention upon the significant subject matter.

Underscoring key words and phrases makes the meaning of a passage stand out boldly. This is an aid during the intensive studying, and later during review. But promiscuous or copious underlining is worse than none at all because it obscures the words and confuses the meaning.

Marginal notes may be of two kinds: (1) supplementing or amplifying the text, (2) outlining the passage's meaning with a few key words, using words from the text or synonyms. The use of question marks, exclamation points, and "catchy" remarks should be avoided because their meaning or significance is sure to be lost at the next reading.

Outlining the subject matter of the text is a splendid although time-consuming way to gain a comprehensive view of the material. There are two advantages of an outline. The first of these is the thoroughness with which one learns his material, and the second is that in preparing an effective outline one must establish the relative significance of the various points of the text. An outline may be made on the margin of the book's pages. But to be fully effective it should be written in a notebook or on a blank page of the textbook, because the outline might not follow the text's sequence of paragraphs.

Briefing is a very valuable aid because to prepare an adequate brief, one must have a thorough understanding of the subject matter. A good brief is a very short summary of the substance of a chapter. Sentences of the brief should be complete in thought and structure in the student's own wording.

Every student should practice **note-taking** right from the beginning. Its value has been demonstrated many times. Engineering students do so much problem work that they are prone to overlook the importance of good note-taking in lectures. Some students argue that they can gain most from the lectures if they listen attentively without taking notes because, they claim, note-taking requires dual concentration. The weakness of their argument is that experience has proved that they cannot and do not retain the essential parts of a lecture without notes.

SUCCESS AFTER COLLEGE

At this point we need a different measure of success. All through the academic process we have measured success in terms of scholastic grades. After college, on the job there are no such simple criteria.

What is success? H. G. Wells says that "wealth, notoriety, place, and power are no measure of success whatever. The only true measure of success is the ratio between what we might have done and what we might have been on the one hand and the thing we have done and thing we have made of ourself on the other."

Another idealistic conception of success is well expressed by "Success is persistent, consistent, systematic application to something worth while." Thus, anyone who sets up a legitimate and worthy goal in life and attains his objective is a successful man.

An editorial in *Mechanical Engineering* for September, 1931, expresses the thought nicely. It says: "How to acquire this powerful quality that is so important to success wherever human beings are concerned we do not know. If a man is not born with it in his character he quite possibly may never acquire it. If he does not cultivate it he squanders a precious heritage. If he does not realize its absence he is likely to be doomed to a thwarted and disappointed career should he attempt one in fields where such a gift is necessary. All in all it is a fundamental to be thoughtfully considered lest a lame man become soured and find life fruitless and unhappy because he cannot run a race."

There are two ways by which success is commonly defined and measured. One is the degree to which a man has achieved material competence, designated usually in terms of his salary or income; the other is the degree to which he has attained eminence in his profession. The first is the best known, most commonly used, and most easily applied of all criteria. It places the emphasis upon material success. The second gives somewhat more attention to spiritual values and tends to emphasize the professional and ethical aspects of success. Data on salaries are relatively easy to obtain. The degree of eminence may be determined by the judgment of one's contemporaries, usually through a questionnaire; inclusion in Who's Who books; a consideration of the special service rendered in one of the professional societies, as holding office and membership in standing committees; and service as a public or corporation official.

Factors That Determine Success

Much has been said about the traits or factors that are determinants of success. Several surveys have been made to find a quantitative answer. The oldest and best known of these surveys was made by C. R. Mann for the Carnegie Foundation in 1916. Later studies have agreed generally with those figures so we may as well look at those data.

He listed **six groups of traits,** as follows:

1. Character, integrity, responsibility, resourcefulness, initiative.
2. Judgment, common sense, scientific attitude, perspective.
3. Efficiency, thoroughness, accuracy, industry.
4. Understanding of men, executive ability.
5. Knowledge of the fundamentals of engineering science.
6. Technique of practice and business.

Returns from this questionnaire, which brought 7,000 replies, showed that the engineers considered the first four of the above group, the character traits, to have contributed 75 per cent to their success, and the last two, the technical traits, to have contributed 25 per cent. Of course, character is essential in any field. Furthermore, the significance of technical proficiency must not be discounted. A man cannot be an engineer at all without a good rating in the technical groups.

Scholarship. Probably a man's scholarship rating is the best single indicator of the range of his success after graduation. This is for the reason that the qualities which enable a man to make a good scholarship record are the qualities which operate to make him successful later.

Several surveys have been made to find, if it can be done, what factors during a man's college life seem to contribute to his success later. From these studies it is safe to draw the following conclusions:

1. No man can succeed without a good character. Without it none of the other traits can matter much.

2. Good scholarship, plus campus achievement, plus a favorable personality are important.

3. A man must be able to adjust himself to the environment of his home and his business.

4. He must have interest in and aptitude for the work which he has selected for his life work.

5. It is important that the organization for which he is working can offer rewards and opportunities which are in line with his fundamental motives.

Plato pointed out the significance of individual differences about 400 B.C. when he wrote that "No two persons are born alike, but each differs from the other in natural endowments, one being suited to one thing and another to another, and all things will be produced in superior quality and quantity and with the greatest ease when each person is engaged in a single occupation for which he is by nature best fitted."

Know thyself is the lesson for the seeker of success. Success is not a will-o'-the-wisp; yet it cannot be measured in absolute terms. Each man must take his own God-given qualities and weave them into a harmonious pattern that will spell success for him. Scholarship, personality, and activities play important parts. Their relative importance will differ as people differ. There is no "most important."

SALARY AND SECURITY

Everyone wishes to have a good salary, and permanence, and security of employment. Perhaps too much emphasis has been placed on security. To some "oldtimers" it seems that some young men are so anxious for security that they are willing to sacrifice future opportunities, which seem to involve some risk, in favor of what appears to be security. However, salary is an impotrant item and the prospective engineer should know about salary scales.

The following tabulation has been adapted from a 1955 report on salaries conducted by the American Society of Civil Engineers.[1] The data are from 103 consulting firms and 7,070 engineers. The figures are annual salaries.

ANNUAL SALARIES FOR ENGINEERS, 1955

	Entrance Rates			Maximum Rates		
Grade	Median	Middle 50%	Total Range	Median	Middle 50%	Total Range
I	$ 3,920	$ 3,660 4,$20	$ 3,140 5,370	$ 4,570	$ 4,210 4,910	$ 3,770 6,220
II	4,480	4,250 4,810	3,600 5,710	5,380	4,970 5,820	4,210 7,270
III	5,110	4,530 5,580	3,770 7,130	5,920	5,500 6,620	4,630 8,840
IV	5,810	5,500 6,050	4,680 7,300	6,800	6,370 7,240	5,350 9,230
V	6,500	6,020 7,160	5,070 8,670	8,140	6,790 8,620	5,960 10,880
VI	7,400	6,630 8,450	5,480 10,800	8,880	8,240 9,850	6,800 13,820
VII	8,560	7,300 9,900	6,470 12,470	10,840	9,390 12,410	8,170 15,430
VIII	9,170	7,940 10,650	6,730 14,630	11,850	10,150 13,910	8,780 20,400
IX	12,820	9,810 16,130	9,230 19,380	17,620	14,810 25,780	11,380 37,600

[1] Proceedings of American Society of Civil Engineers, Vol. 81, Paper No. 761, August, 1955.

This tabulation has been arranged to give a wide range of information about salaries. The entrance rates and the maximum rates are given for each grade. For example, in Grade I some men began as low as $3,140 and as high as $5,370 per year. In the middle fifty per cent of the beginners the range was from $3,660 to $4,120 per year. The median, which is the middle (not the average) of any group of figures, was $3,920 for this middle fifty per cent. The striking feature of the salaries is the wide range between the lowest and the highest. Again referring to Grade I, we note that salaries in this grade varied from $3,140 to $6,220 per year. It will be noted, too, that there is an overlap in salaries from one grade to the next one.

These are professional grades adopted by the American Society of Civil Engineers in 1946, and based on professional grades of the U. S. Civil Service Commission that were designated P-1 through P-9 before 1949 and GS-5 to GS-16 after that date. "These classifications include all classes of positions, the duties of which are to perform operational, creative, advisory, administrative, or research work which is based on the established principles of civil engineering profession. The fundamental prerequisite for every position to be classified in these grades is professional, scientific, or technical training equivalent to that represented by graduation from a college or university of recognized standing."

"Grade I includes all positions, which involve, under immediate supervision, the performance of fundamental civil engineering duties requiring professional training but little or no experience (Federal GS-5)."

The successive grades call for increasing experience and responsibility to reach Grade IX.

"Grade IX includes all positions, such as

a) the administrative and professional head of an important engineering organization with full authority and responsibility for conceiving and executing all the plans and functions of the organization, directing an administrative and professional engineering staff engaged in varied important projects; or

b) positions requiring highly specialized professional engineering or scientific ability (Federal GS-16)."

There is a growing tendency in many trades and some professions to fix wages or salaries by some artificial means. This is done by controlling the entrance requirements or the number of entrants and the method of entrance of those who would join the group; or through the establishment of bargaining agencies that are powerful enough to use whatever means are necessary to enforce their demands. Labor unions are the best-known example of the latter. There are active and aggressive groups who believe that engineers should become members of the organized union movement. Most professional engineers oppose that point of view.

Factors That Determine Salaries

Engineering salaries depend upon many factors, among which are: the type of industry, the prosperity and progressiveness of the industry, character of work, degree of skill required, supply of engineers, number of possible employers, standard and cost of living, hazards of work, regularity and permanence of employment, vacation and pension provisions, section of the country, professional growth of the engineers, and others.

It has been said facetiously that a man can put up with anything if he is paid enough. Actually, each man must determine the weight which he personally wishes to give to the several factors that influence his salary and living conditions. A surprisingly large number of men become unhappy, or imagine that they are unhappy, in a certain section of the country and express a desire to get back to "God's Country"; others wish to live in a small (or a large) city; others must be near kinfolks; others are bothered by the climate.

Leaving these more or less whimsical factors aside, there are some significant items that should receive consideration. The most important thing to remember is that in choosing an engineering career one chooses with it certain elements and conditions of employment. These have been discussed under the various departments and employment opportunities. We have mentioned the cost of living, which includes food, rent, clothing, and transportation. Another item is the permanence and the continuity of tenure. Some positions carry fairly high list salaries; but layoffs without pay, or a reduction in the number of working hours with a corresponding reduction in pay, are frequent. Some include vacations with pay; some include sick leave; some include bonus provisions; some include provisions for retirement. Environment, both working and living, will become increasingly important as one becomes older and has a family for whom he desires pleasant, healthful, and convenient surroundings.

In many cases, size of beginning salary is not the most significant item, because opportunities to advance will have greater weight, finally. This brings us to an important point which is overlooked by many men in their eagerness to get ahead. Present inconveniences and hardships form a substantial and solid portion of the foundation upon which permanent success is built. A young man should be careful to avoid passing judgment too hastily, particularly in cases where his present job displeases him. He sees other men who seem to be doing better than he thinks he is. It would be enlightening for him if he could know what those favored (he thinks) men are thinking about their jobs.

Most salary studies agree that (1) the difference in earning power between highly paid men and men in the middle and lower salary ranges is strikingly great, and that (2) the higher salaried men are those who combine with their technical ability the capacity to handle independent businesses or to manage men or affairs.

Appendix

Counselors and teachers who are authorized to use tests will find the following ones helpful; many of them are long-established.

OTIS: *Quick Scoring Mental Ability Test,* World Book Co., 2126 Prairie Ave., Chicago, Illinois, 1922.

School and College Ability Tests, Cooperative Test Division, Educational Testing Service, Princeton, New Jersey, 1955.

SULLIVAN *et al.*: *California Short Form Test of Mental Maturity,* California Test Bureau, 3636 Beverly Blvd., Los Angeles, California, 1942.

TERMAN-MCNEMAR: *Test of Mental Ability,* World Book Co., 2126 Prairie Ave., Chicago, Illinois, 1941.

THURSTONE: *American Council on Education Psychological Examination, College Edition, 1947,* American Council on Education, 744 Jackson Place, Washington, D. C.

TOOPS: *Ohio College Association Psychological Examination, 1944,* Psychology Dept., Ohio State University, Columbus, Ohio.

MECHANICAL APTITUDE

BENNETT: *Test of Mechanical Comprehension,* Psychological Corporation, 522 Fifth Ave., New York, N. Y., (AA—1940; BB—1941).

CASE-RUCH: *Survey of Space Relations Test,* California Test Bureau, 3636 Beverly Blvd., Los Angeles, California, 1944.

CRAWFORD: *Spatial Relations Test,* Psychological Corporation, 522 Fifth Ave., New York, N. Y., 1940.

LAPP-CHITTENDEN-STUIT: *Physical Science Aptitude Test,* Bureau of Educational Research and Service, State University of Iowa, Iowa City, Iowa, 1943.

LAWSHE: *Purdue Industrial Training Classification Test,* Science Research Associates, 228 S. Wabash Ave., Chicago 4, Illinois, 1942.

LIKERT-QUASHA: *Revised Minnesota Paper Form Board,* Psychological Corporation, 522 Fifth Ave., New York, N. Y., 1939.

MELLENBRUCH: *Mechanical Aptitude Test for Men and Women,* Science Research Associates, 228 S. Wabash Ave., Chicago 4, Illinois, 1944.

MILLER: *Survey of Mechanical Insight,* California Test Bureau, 3636 Beverly Blvd., Los Angeles, California, 1945.

MILLER: *Survey of Object Visualization,* California Test Bureau, 3636 Beverly Blvd., Los Angeles, California, 1945.

Minnesota Manual Dexterity Test, Educational Test Bureau, 720 Washington Ave., S. E., Minneapolis, Minnesota, 1933.

Minnesota Mechanical Assembly Tests, Marietta Apparatus Company, Marietta, Ohio, 1930.
Minnesota Spatial Relations Test, Marietta Apparatus Company, Marietta, Ohio, 1930.
O'ROURKE: *Mechanical Aptitude Test,* Psychological Corporation, 522 Fifth Ave., New York, N. Y., 1940.
OWENS-BENNETT: *Test of Mechanical Comprehension,* Psychological Corporation, 522 Fifth Ave., New York, N. Y., 1947.
Pennsylvania Bi-Manual Work Sample, Psychological Corporation, 522 Fifth Ave., New York, N. Y., 1945.
Purdue Pegboard, Science Research Associates, 228 S. Wabash Ave., Chicago 4, Illinois, 1943.

VOCATIONAL INTEREST INVENTORY

BRAINARD: *Occupational Preference Inventory,* Psychological Corporation, 522 Fifth Ave., New York, 1945.
CLEETON: *Vocational Interest Inventory,* McKnight & McKnight, 109 W. Market St., Bloomington, Illinois, 1943.
GARRETSON-SYMONDS: *Interest Questionnaire for High School Students (boys),* Bureau of Publications, Teachers' College, Columbia University, New York, N. Y., 1942.
Kuder Preference Record, Science Research Associates, 228 S. Wabash Ave., Chicago 4, Illinois, 1942.
LAYTON: *Engineering Aptitude Test,* Student Counseling Service, University of Minnesota, Minneapolis, Minn., 1953.
LEE-THORPE: *Occupational Interest Inventory,* California Test Bureau, 3636 Beverly Blvd., Los Angeles, California, 1943.
Pre-engineering Ability Test, Educational Testing Service, Princeton, New Jersey, 1951.
Strong's Vocational Interest Blank, Stanford University Press, Stanford University, California, 1938.

COOPERATIVE TEST SERVICE ACHIEVEMENT TESTS

Cooperative Test Service, 437 West 59th St., New York, N. Y.
These are tests of the American Council on Education. They cover English, Mathematics, Foreign Languages, Chemistry, Geology, etc.

VOCATIONAL READING

The following books contain information which continues to be of help to the reader who wishes to pursue this study of the fields of engineering more thoroughly.

1. *An Introduction to the Engineering Profession.* McGuire and Barlow. Addison-Wesley Press, Cambridge, Mass., 2nd ed., 1954.
2. *Building an Engineering Career.* C. C. Williams. McGraw-Hill Book Company, New York, N. Y., 1946.
3. *Engineering Feats.* Archibald Williams. Thomas Nelson & Sons, Ltd., New York, N. Y., 1925.
4. *Engineering Opportunities.* R. W. Clyne. D. Appleton-Century Company, New York, N. Y., 1939.
5. *Great Engineers.* Prof. C. Matschoss. G. Bell & Sons, Ltd., London, England, 1939.
6. *How To Be an Engineer.* Fred D. McHugh. Robert McBridge & Company, 116 E. 16th Street, New York, N. Y., 1940.
7. *Master Builders of 60 Centuries.* John A. Miller, D. Appleton-Century Company, New York, N. Y., 1938.

8. *Mighty Engineering Feats.* Harriet Salt. Penn Publishing Company, Philadelphia, Pennsylvania, 1937.
9. *The Book of Electrical Wonders.* Ellison Hawks. Lincoln Macveagh, The Dial Press, New York, N. Y., 1929.
10. *The Engineer, His Work and His Education.* R. L. Sackett. Ginn & Company, New York, N. Y., 1928.
11. *The Engineering Profession.* Hoover and Fish. Stanford University Press, Stanford University, California, revised ed., 1950.
12. *The Engineer in Society.* John Mills. D. VanNostrand, New York, N. Y., 1946.
13. *The Romance of Engineering.* A. D. Merriman. G. G. Harrap & Company, Ltd., London, England, 1934.
14. *The Story of Engineering.* J. Gardner Bennett. University of Knowledge, Inc., Chicago, Illinois, 1939.
15. *The World of Machines.* Percy M. Baker. W. Gardner, Darton & Company, Ltd., London, England, 1927.
16. *The Young Engineer.* Charles B. Broschart. Exposition Press, New York, N. Y., 1953.
17. *Vocational Guidance in Engineering Lines.* American Association of Engineers. Mack Printing Company, Easton, Pennsylvania, 1933.
18. *What Engineers Do.* Walter D. Binger. W. W. Norton & Company, New York, N. Y., revised ed., 1938.
19. *Your Career in Engineering.* Norman V. Carlisle. E. P. Dutton and Company, New York, N. Y., 1942.