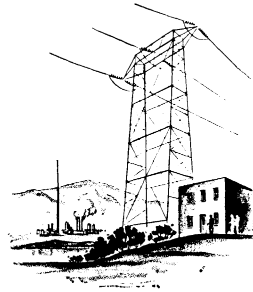

chapter 4

# 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."