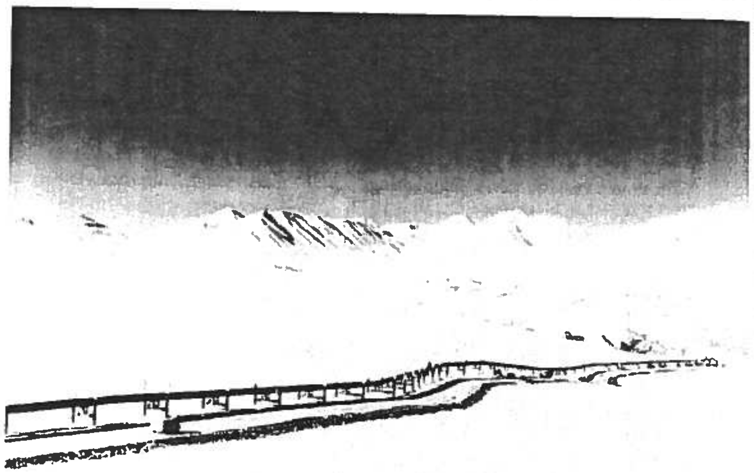
An Exemplary Engineering Achievement



The 800-mile Alaska Pipeline carries vital oil under and over some of the most hostile terrain in the world. The 48-inch-diameter steel line burrows through mountains, across rivers and lakes, and over permanently frozen ground on stilts. (Courtesy of the American Council of Engineering Companies.)

CHAPTER TWO

DEFINITION OF ENGINEERING

2.1 ENGINEERING

The Accreditation Board for Engineering and Technology (ABET) defines engineering as "the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind." (*1*)

Embodied in that definition are certain fundamental elements that describe the essence of engineering. Engineering is a profession. Like law, medicine, architecture, teaching, and the ministry, it aspires to high standards of conduct and recognizes responsibilities to clients, peers, and to society as a whole. It is based on a special body of knowledge, and its members attain professional status through well-defined avenues of education and training.

Engineering is based on a knowledge of mathematical and natural sciences.

> *Both the engineer and scientist are thoroughly educated in the mathematical and natural sciences, but the scientist primarily uses this knowledge to acquire new knowledge, whereas the engineer applies the knowledge to design and develop usable devices, structures and processes. In other words, the scientist seeks to know, the engineer aims to do. (2)*

In the words of Theodore von Kármán (*3*): "Scientists explore what is; engineers create what had not been."

Glegg (*4*) contrasted the function of scientists and engineers as follows:

It seems fashionable to glamorize the position of the scientist and to imply that no other occupation is so rewarding in human, if not material, values. I do not think that this is true for several reasons. For instance, the engineer has the much wider horizon of possibilities. A scientist is lucky if he makes one real creative addition to human knowledge in his whole life, and may never do so.

An engineer has, by comparison, almost limitless opportunities. He can, and frequently does, create dozens of original designs and has the satisfaction of seeing them become working realities. He is a creative artist in a sense never known by the pure scientist. An engineer can make something. He creates by arranging in patterns the discoveries of science past and present, patterns designed to fit the ever more intricate world of industry. His material is profuse, his problems fascinating, and everything hinges on personal ability.

Engineering is viewed as an art as well as a science. It is perceived to embody a system of principles, methods, and skills that cannot be learned simply by study. It must be learned, at least in part, by experience and professional practice.

The engineer's knowledge must be tempered with professional judgment. Solutions to engineering problems must satisfy conflicting requirements, and the preferred optimum solution does not always result from a clear-cut application of scientific principles or formulas. The engineer must weigh conflicting constraints and make judgments based on knowledge and experience, seeking a best or optimum solution.

In seeking answers to problems, engineers utilize the materials and forces of nature. There is an almost unlimited list of materials, both natural and manufactured, that engineers can utilize to fashion their designs. They select appropriate materials on the basis of availability, cost, and physical properties (weight, strength, durability, elasticity, and so forth).

The engineer can access a much smaller list of sources of energy: petroleum, coal, gas, nuclear fission, hydroelectric power, sunlight, and wind. These sources vary widely in availability, cost, safety, and technological complexity.

Engineers recognize that the earth's supply of materials and energy is not limitless, and they must be concerned not only with utilization of these resources but also with their conservation. This involves recycling and reuse of existing materials, rehabilitation instead of replacement of old facilities, and the creative substitution of an abundant material for one that is in scarce supply. It also involves seeking solutions that are energy efficient and exploring for new sources of energy to replace those that are being depleted.

Engineers seek solutions that are economical. This implies that the benefits of their solutions must exceed the costs. It further means that they must exercise care in the management of money, time, materials, and other resources.

A. M. Wellington (*5*) emphasized this point in 1887 with this whimsical definition of engineering:

It would be well if engineering were less generally thought of ... as the art of constructing. In a certain important sense it is the art of not constructing ... of doing that well with one dollar which any bungler can do with two after a fashion.

Up until the late 1960s, economics was the principal constraint on the planning and building of engineering works. There was little concern about harmful environmental effects that accompanied the construction of airports, highways, buildings, and other facilities. A dramatic turnabout in public and official concern about the environmental impact of technological achievements culminated in the passage of the National Environmental Policy Act of 1969. This legislation requires that an environmental impact statement be prepared for federally funded projects that might cause environmental harm. Its passage reflected greater awareness of the need for engineers to weigh the negative effects of their projects as well as the benefits. Engineering must be practiced with appropriate awareness and concern for the possible harmful impacts of technology on people and the environment.

Ultimately, all of the engineer's work must benefit mankind. Recognition of this fact is demonstrated by the enactment of professional engineering registration laws in the various states for the purpose: "to safeguard life, health and property, and to promote the public welfare." Engineers must objectively evaluate their designs to insure that the positive effects exceed any adverse effects and that, on balance, their solutions are for the public benefit.

2.2 ENGINEERING SUPPORT PERSONNEL

Although it is possible for engineers to work alone, more commonly they work with a group of support personnel. The engineer and the support personnel comprise the engineering team, and the roles of each specialty group are often described in terms of an occupational spectrum. This spectrum includes the engineer, engineering technologists, engineering technicians, and craftsmen, arranged vertically as Table 2.1 illustrates.

At the top of the spectrum is the engineer who serves as innovator, designer, decision maker, and leader of the engineering team. Next is the engineering technologist, who assists the engineer in the planning, construction, and operation of engineering facilities. Typical activities for technologists include technical sales, construction supervision, routine product development, and coordination of work force, equipment, and materials. The engineering technologist's post-secondary education consists of a four-year program of study culminating in a Bachelor of Engineering Technology degree. The educational emphasis of the technologist's program of study is less theoretical and less mathematical than that of an engineer, but is more hardware and process oriented (*6*).

Engineering technicians are specialists in methodology devoted to the accomplishment of practical objectives. Typical activities of technicians

TABLE 2.1 ***The Engineering Team***

Specialist	Typical Activities
Engineer	Conceptual design Research Project planning Product innovation System development Supervision of technologists, technicians, and craftsmen
Technologist	Routine product development Construction supervision Technical sales Hardware design and development Coordination of work force, materials, and equipment Supervision of technicians and craftsmen
Technician	Drafting Estimating Field inspections Data collection Surveying Technical writing
Craftsman	Uses hand and power tools to service, maintain, and operate machines or products useful to the engineering team

include drafting, surveying, estimating, collecting data, and performing field inspections on construction projects. Technicians normally have been trained in a two-year program in engineering technology leading to an associate degree.

Craftsmen are skilled workers who produce the materials and products or facilities specified by the design. Such specialists include electricians, carpenters, welders, machinists, and model builders. Craftsmen normally acquire their skills by on-the-job training; their education typically does not extend beyond high school.

It should be noted that the role of the engineering technologist in the occupational spectrum is not well defined. That occupation emerged in the early 1970s as two-year educational programs for technicians were expanded to four-year programs leading to a baccalaureate degree. Although the educational distinction between technologists and technicians is clear, the functions often overlap. The functional differences between technologists and engineers are likewise blurred. Kemper (7) explains:

> *Technologists are supposed to work in that part of the engineering spectrum which lies between the engineer and the technician, in the routine aspects of product development, manufacturing planning, construction supervision, or technical sales. However, as is often the case, individual human talents may prove to be more important than the intentions of educational programs, and it has been observed that many persons educated as technologists have actually emerged in industry functioning as engineers. Since their educations bear strong resemblances to those of engineers, such a development should not be especially surprising.*

ENGINEERING FIELDS OF SPECIALIZATION

Engineering is a diverse profession. It is composed of several major branches or fields of specialization and dozens of minor branches. Engineers have created these branches in response to an ever-widening base of technological knowledge. In the following paragraphs, some of the more prominent branches of engineering are characterized. These are taken up in general order of decreasing size of the discipline. It should be remembered that there is considerable overlap among the various specialties. It is not uncommon for an engineer to practice more than one specialty within a major branch during the course of his or her career.

2.3 ELECTRICAL ENGINEERING

The largest of all engineering branches, electrical engineering is concerned with electrical devices, currents, and systems. Electrical engineers work with equipment ranging from heavy power generators to tiny computer chips. Their work contributes to almost every sector of society: electrical appliances for homes, electronic displays for business, lasers for industry, and satellite systems for government and businesses.

Electrical engineers usually work in one of six specialty areas:

1. Power generation and transmission.
2. Electronics.
3. Communications systems.
4. Instrumentation and measurement.
5. Automatic controls.
6. Computers.

Electrical engineers are responsible for the generation, transmission, and distribution of electric power. They locate hydroelectric, steam, diesel engine, and nuclear power plants, and specify the engines, generators, and auxiliary equipment for these plants. These engineers have contributed to the development of electric-generating stations in the United States that have a capacity of about 700 million kilowatts and generate over 3 trillion kilowatt-hours of power annually.

One of the most vibrant specialties in electrical engineering is the field of electronics. Generally speaking, this field deals with the emission, behavior, and effects of electrons. Electronics engineers design efficient circuits using a variety of electric elements that can produce, amplify, detect, or rectify electrical signals.

Electronics has applications in communications, power, transportation, medicine, and many other fields. With the advent of transistors, semiconductor diodes, integrated circuits, and lasers, electronic technology has changed dramatically in recent years. These and other advances provide even greater opportunities for rewarding work for electrical engineers in the field of electronics.

Electrical engineers have made and continue to make significant contributions to the field of communications. They use their knowledge of wave propagation, electromagnetic theory, and electronic principles to design radio, telephone, television, and satellite communication systems. Approximately 7 percent of electrical engineers work in the communications specialty.

Another small but important specialty area in electrical engineering is instrumentation and measurement. Engineers in this specialty are concerned with the use of electronics to make measurements needed for research, development, and operation. They have devised electronic instruments to measure a wide variety of properties and quantities such as temperature, speed, pressure, and flow rate. These instruments have broad applications in business and industry and contribute in many ways to public health and safety.

Increasingly, electronic engineers are employing the concept of feedback control to automatic operations and processes. Such systems compare a measured quantity (e.g., temperature, pressure, etc.) to a desired standard and automatically make appropriate adjustments to the mechanism or system to minimize any difference between the measured and the desired quantity or property.

Electrical engineers apply electrical and mechanical principles to design and construct electronic computers. They perform research in computer circuitry, develop new methods of data processing and storage, and seek new ways to apply computers to various types of data-processing problems.

As Table 2.2 illustrates, computer engineering has grown to be one of the largest branches in engineering. It is discussed more fully in the following section.

2.4 COMPUTER ENGINEERING (*8*)

Computer engineering is the field of engineering responsible for the design and implementation of digital systems and the integration of computer technology into an increasing number of systems and applications. It is a relatively new and rapidly growing engineering discipline with extraordinary challenges and opportunities. Since the invention of the transistor in 1947, technological advances in computer engineering have been astounding. Today, it is possible to integrate more than 100 million transistors in a single integrated circuit chip. At the same time, the switching speed of transistors has increased more than 10,000 fold, and it is now possible to design chips that operate at more

than one billion operations per second. This rapid improvement in computer technology has challenged computer engineers: (1) to invent hardware and software design, and the tools to develop these integrated circuit chips and (2) to imagine, design, and verify systems containing these chips.

Rapid advances in computer technology, resulting in ever smaller, less costly, high-performance computers, have resulted in a vast number of applications containing embedded computers as elements. These range from highly complex communications systems to biomedical imaging devices, sophisticated consumer products, and household appliances.

BIOENGINEERING

Bioengineering is an interdisciplinary field that applies engineering principles to the study of biological processes. The purpose of bioengineering research is to develop new and better physical and mathematical concepts and techniques that address problems in medicine and biology. Bioengineering is being applied to a wide variety of problems, including the design and development of new medical devices such as assistive devices for people with spinal cord injuries and sensory aids for people with poor vision. Recent bioengineering research has included the development of ultrasonic and magnetic resonance instrumentation, which produce better imaging for medical diagnoses and treatment (*9*).

2.5 MECHANICAL ENGINEERING

One of the oldest and broadest areas of engineering activity, mechanical engineering, is concerned with machinery, power, and manufacturing or production methods. Mechanical engineers design and manufacture machine tools—the machines that make machines—and machinery and equipment for all branches of industry. For example, they design turbines; printing presses; earth-moving machinery; food processors; air conditioning and refrigeration systems; artificial hearts and limbs; and engines for aircraft, diesel locomotives, automobiles and trucks, and public transportation vehicles. Their machines move and lift loads, transport people and goods, and produce energy and convert it to other forms.

In the power specialty, mechanical engineers are involved in the design, production, and operation of hydraulic turbines for driving electric generators and of boilers, engines, turbines, and pumps for the development of steam power. They design and operate power plants and concern themselves with the economical combustion of fuels, the conversion of heat energy into mechanical power, and the use of that power to perform useful work.

In heating, ventilation, and air conditioning, mechanical engineers provide controlled conditions of temperature and humidity in homes, offices, commercial buildings, and industrial plants. They develop equipment and systems needed for the refrigeration of foods and the operation of cold storage warehouses and ice manufacturing plants.

Mechanical engineers work closely with industrial engineers and managers in many fields of manufacturing, designing imaginative machinery and systems that yield great economies in production.

Mechanical engineers may also be found working in marine engineering, designing machinery for boats, naval vessels, and merchant ships; in the automotive industry designing and manufacturing automobiles, trucks, and buses; and in the aerospace industry working in the design of new aircraft and spacecraft.

Mechanical engineering is a broad field that deals with diverse engineering problems. Its members can often be found in interdisciplinary activities such as automation, computer technology, and microelectromechanical systems (MEMS).

MICROELECTROMECHANICAL SYSTEMS (MEMS)

MEMS is an emerging interdisciplinary discipline that involves electrical engineering, mechanical engineering, and in some cases, bioengineering. MEMS stands for microelectromechanical systems. MEMS are physically small systems that have both electrical and mechanical components. Examples of such devices include inkjet-printer cartridges, accelerometers that deploy automobile airbags, and miniature robots. These systems typically have sensors that, because of their small physical size, can measure the environment without significantly modifying it. Examples of microsensors include devices that can measure pressure, acceleration, strain, temperature, vibration, proximity, sound, and many others. MEMS devices commonly include microactuators which interact with their environment. Microactuators are useful because the amount of work they perform on the environment is small; they can therefore be very precise. MEMS can be placed in small spaces, such as inside automobile engines, small appliances, and living organisms, to measure and affect their environment (*10*).

2.6 CIVIL ENGINEERING

Civil engineering affects many of our daily activities: the buildings we live in and work in, the transportation facilities we use, the water we drink, and the drainage and sewerage systems that are necessary to our health and well-being (see Figure 2.1). Civil engineers:

- Measure and map the earth's surface.

- Design and supervise the construction of bridges, tunnels, large buildings, dams, and coastal structures.
- Plan, lay out, construct, and maintain railroads, highways, and airports.
- Devise systems for the control and efficient flow of traffic.
- Plan and build river regulation and flood control projects.
- Provide plants and systems for water supply and sewage and refuse disposal.

Civil is a very broad branch of engineering, and it includes at least seven major specialized areas of practice:

1. Structural engineering.
2. Construction engineering and management.
3. Transportation engineering.
4. Geotechnical engineering.
5. Hydraulic and water resources engineering.
6. Environmental engineering.
7. Geodetic engineering.

The largest specialty within civil engineering, structural engineering, is concerned with the design of large buildings, bridges, tanks, towers, dams, and other large structures. These engineers design and select appropriate structural

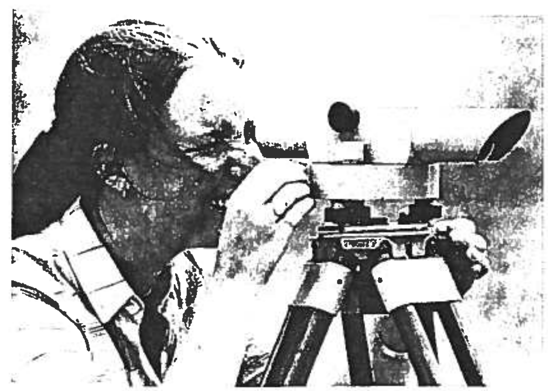


Figure 2.1 *Geodetic engineering, a branch of civil engineering, involves measuring and mapping the earth's surface. (Courtesy of Institute Communications and Public Affairs, Georgia Institute of Technology.)*

components (e.g., beams, columns, and slabs) and systems to provide adequate strength, stability, and durability.

A large fraction of civil engineers work in the construction industry, building the facilities that other engineers and architects design. The task of construction engineers is to utilize and manage the resources of construction (the vehicles, equipment, machines, materials, and skilled workers) to produce with timeliness and efficiency the structure or facility envisioned by the designer.

Transportation engineers are concerned with the planning and layout of highways, airports, harbors and ports, and mass transportation systems. They plan and design transportation terminals and devise and operate systems for the control of vehicular traffic.

Geotechnical engineers are concerned with the structural behavior of soil and rock. They analyze earth support systems and design foundations, earth walls, and highway and airport pavements.

Hydraulic and water resources engineers are concerned with the flow of water through ditches, conduits, canals, dams, and estuaries. They use their special knowledge of fluid mechanics to design dams, irrigation systems, municipal water works, and drainage and erosion control systems.

Environmental engineers are concerned with solid waste management, air and water pollution, and control of pesticides and radiological hazards. They design and oversee the operation of water treatment and sewage treatment plants and measure and monitor pollutants in the air, on land, and in lakes and streams.

Geodetic engineers measure and map the earth's surface. They locate precisely property and building lines and survey the locations, elevations, and alignment of engineering projects.

Civil engineers work with construction companies, manufacturing companies, power companies, and with consulting engineering firms. Many opportunities for civil engineering employment exist in city, county, and state engineering departments and in the various agencies of the federal government.

2.7 CHEMICAL ENGINEERING

Chemical engineering involves the application of chemistry, physics, and engineering to the design and operation of plants for the production of materials that undergo chemical changes during their manufacture (*11*). Such materials include various chemicals, such as paints, lubricants, fertilizers, pharmaceuticals and cosmetics, petroleum products, foods, metals, plastics, ceramics, and glass.

In these and other industries, chemical engineers are responsible for creating systems for producing large quantities of materials that chemists make in small quantities in the laboratory. Chemical engineers select appropriate processes and arrange them in proper sequence to produce the desired product. These include:

1. Heat transfer processes.
2. Mass transfer processes such as absorption, humidification, and drying.

3. Processes that involve mechanical action such as mixing, crushing, grinding, sizing, and filtering.
4. Processes that involve chemical reaction, including chlorination, polymerization, oxidation, and reduction (*6*).

Chemical engineers are in demand in practically all types of manufacturing. Looking to the future, a vigorous and expanding demand for chemical engineers is expected as manufacturers continue to develop new products in response to people's pursuit of better health and a higher standard of living. Chemical engineers can also be expected to play a major role in finding solutions to some of mankind's most challenging problems, for example, environmental pollution, depletion of energy supplies, and world overpopulation and hunger.

2.8 INDUSTRIAL ENGINEERING

Industrial engineers are concerned with the design, improvement, and installation of integrated systems of people, materials, and energy in the production of either goods or services (*7, 12*). They engineer processes and systems that improve quality and productivity (*13*). They are primarily interested in problems that involve economy in the use of money, materials, time, human effort, and energy (*11*). They are more concerned with the "big picture" of industrial management and production than with the detailed development of processes (*3*).

Most of the activities of industrial engineers fall into one of four categories:

- Those related to plant layout.
- Those designed to increase worker productivity.
- Those designed to control the quality of products.
- Those designed to reduce and control costs.

Plant layout involves determining the floor space needed for each production component—workers, equipment, and materials handling and storage—and arranging and sequencing the various operations to insure a safe, smooth, and efficient operation.

Industrial engineers perform time and motion studies of workers, set standards of work performance, and propose new and improved work methods to increase productivity. They employ quality control techniques to reduce waste and customer complaints. They use statistical procedures to establish reasonable tolerances in quality and develop procedures for making routine checks of product quality. In all of their work, industrial engineers must carefully monitor costs of production and seek ways to reduce costs without compromising product quality.

Although most industrial engineers are employed by manufacturing industries, they may also be found working in other settings such as in hospitals; airlines; railroads; retail businesses; and municipal, state, and federal government agencies.

2.9 AEROSPACE ENGINEERING

Aerospace engineering is concerned with all aspects of vehicular flight at all speeds and altitudes. It covers all phases of research, design, and development in this broad area that includes hovercraft designed to operate a few feet above land and water, helicopters that hover and maneuver in all directions, a variety of conventional airplanes, and complex spacecraft for orbiting the earth and exploring the solar system. The term *aeronautical engineering* is used to refer to the engineering of atmospheric flight, while *astronautical engineering* deals with space flight.

Aerospace engineers commonly work in one of several specialty areas such as aerodynamics, structural design, propulsion systems, and guidance and control.

Aerodynamics involves the efficient design of external surfaces of aerospace vehicles. Aerodynamics engineers supervise the performance of wind tunnel tests; measure and predict the forces of lift and drag; and develop and test theories of flight performance, stability, and control.

In aerospace engineering, structural designers seek to design and build aircraft systems that can be operated economically. This usually translates into maximizing the vehicle strength-to-weight ratio. They also study the response of aircraft structures to mechanical vibrations and other dynamic forces and design structures capable of withstanding these forces.

Aerospace engineers develop and refine propulsion systems for aircraft and spacecraft. The thrust for all of the many propulsion systems for aerospace craft is produced by accelerating a fluid rearward. In the case of the turbojet, burning fuel produces hot gas that is expanded further by a jet nozzle, providing the thrust. In other systems such as helicopters and small, low-speed aircraft, the propulsion is provided by a propeller driven by an engine that develops its power by compressing, burning, and expanding its fuel.

In the guidance and control specialty, engineers develop instruments for conventional aircraft that provide information directly to a pilot or automatically navigate, maneuver, or control the aircraft.

These specialists also develop systems that guide and control the trajectories of missiles. Such systems track the missile by radar or on-board equipment, compute and communicate the necessary corrections, and correct precisely the direction and velocity by vernier rockets (*6*).

Aerospace engineering offers one of the most exciting and challenging fields of activity for those who choose engineering as a career.

2.10 MATERIALS ENGINEERING

The term *materials engineering* refers in a general way to a group of engineering specialties that are concerned with the development, production, fabrication, and use of materials in specific technologies. Some of these specialties are:

Metallurgical engineering, which is concerned with the production of metals from ores and the development of metallic alloys.

Mining engineering, which encompasses the exploration, location, development, and operation of mines for extracting coal, metallic ores such as copper and zinc, and other minerals.

Petroleum engineering, which is concerned with the exploration, extraction, storage, and transportation of crude petroleum and natural gas.

Plastics engineering, which involves the formulation, manufacture, and applications of materials (e.g., polymers) that permanently deform under stress.

Ceramic engineering, which deals with products manufactured or used at high temperatures (above 1000°F) and the physical and chemical processes used in their manufacture.

Population growth, industrialization, and depletion of the world's natural resources should contribute to a strong and sustained future demand for materials engineers.

2.11 OTHER BRANCHES OF ENGINEERING

In the preceding paragraphs, some of the more prominent branches of engineering have been described. There are many more engineering specialties, but space limitations preclude a detailed description of these disciplines. Brief descriptions of some of these specialties follow.

- *Architectural engineers* work closely with architects to plan, design, and build large structures.
- *Oceanographic engineers* work with scientists to explore and study the oceans and to develop ways to utilize them for human benefit.
- *Operations researchers and systems engineers* apply advanced mathematical and computer-based techniques such as linear programming, queuing theory, and simulation to quantitatively predict the behavior of large systems.
- *Nuclear engineers* apply scientific and engineering principles to the design, development, and use of nuclear power systems.
- *Textile engineers* are concerned with the planning, design, and operation of manufacturing plants in the textiles industry.
- *Agricultural engineers* apply engineering principles, machines, materials, and energy to the production and processing of food products.

Table 2.2 shows the numbers of engineers employed in the various fields of engineering. Table 2.3 gives the percentages of employed engineers by sector of employment for six major engineering branches.

TABLE 2.2 ***Employed Engineers by Field, 1998***

Field	Employment
Aerospace engineers	53,035
Chemical engineers	48,363
Civil engineers	195,028
Computer engineers	299,308
Electrical/Electronic engineers	356,954
Industrial engineers	126,303
Materials engineers	19,654
Mechanical engineers	219,654
Mining engineers	4,444
Nuclear engineers	11,694
Petroleum engineers	12,061
All other engineers	414,611

Source: Engineers, Vol. 6, No. 1, Engineering Workforce Commission of the American Association of Engineering Societies, Washington, DC, Spring, 2000.

TABLE 2.3 ***Percentages of Employed Engineers by Major Field and Sector of Employment***

Sector of Employment	Aeronautical/ Astronautical	Chemical	Civil	Electrical/ Electronic	Industrial	Mechanical
Industry	63.3	74.0	48.9	69.6	76.7	75.8
Self-employed	11.1	12.7	14.4	12.2	11.5	11.4
Educational institutions	3.5	5.0	3.0	4.9	3.6	3.9
Nonprofit organizations	2.4	1.7	0.5	1.5	1.7	1.1
Federal government	14.7	4.6	9.3	9.3	4.6	6.1
Military	4.3	0.3	1.3	0.9	0.3	0.4
State/local/ other government	0.4	1.3	22.1	1.1	1.4	0.9
Other	0.3	0.4	0.5	0.5	0.2	0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: U.S. Scientists and Engineers: 1988, Surveys of Science Resources Series, Selected Statistical Tables, National Science Foundation, Washington, DC.

2.12 FUNCTIONS OF ENGINEERING

Within a given engineering field of specialization, there is a wide range of functions or activities in which engineers may be involved (*8*). Engineers can be involved in some combination of these functions, and, conceivably, could

perform all of them over the course of a career. These functions include: research, development, design, production, construction, operations, sales, and management.

1. *Research* involves seeking new knowledge or a better understanding of the significance and relationship of facts already known.
2. *Development* involves making the discoveries and results of research available in the form of useful products, methods, or processes.
3. *Design* is the process of converting concepts and information into detailed plans and specifications from which a finished product or facility can be manufactured or constructed.
4. *Production* is the industrial process by which products or articles are manufactured from raw materials.
5. *Construction* is the process of translating designs and materials into structures and facilities such as buildings, highways, and power and communication facilities.
6. *Operations* in engineering means the application of engineering principles or the performance of practical work. In manufacturing, operations involve procuring supplies, maintaining plant, and directing personnel. Engineers are prominently involved in the operations of utility companies, railroads, communications companies, and traffic control systems for large cities.
7. *Sales* in technological industries often requires the services of trained engineers to recommend the machines, tools, parts, or services to best serve the customers' needs.
8. *Management* positions in many industries are occupied by engineers. They are responsible for the solution of problems of policy, finance, organization, public relations, and sales. They also have the responsibility for the selection and supervision of personnel and the coordination of research, development, production, and all other departments.

Table 2.4 shows the percentages of employed engineers by primary work activity for six major fields of engineering.

CAREER PATHS FOR ENGINEERS (14)

There are at least seven career options for graduating engineering students:

1. The corporate ladder.
2. The independent entrepreneur.
3. The military.
4. Engineering and social service abroad.
5. The professor-engineer.

TABLE 2.4 ***Percentages of Employed Engineers by Major Field and Primary Work Activity***

Primary Work Activity	Aeronautical/ Astronautical	Chemical	Civil	Electrical/ Electronic	Industrial	Mechanical
Basic research	1.6	1.0	0.3	0.8	0.2	0.6
Applied research	7.7	4.9	1.8	4.5	0.8	3.2
Development	37.1	28.7	13.2	37.9	17.9	39.0
Management of research and development	17.5	12.3	3.2	13.3	5.9	10.4
Other management/ administration	9.0	21.7	33.6	14.6	28.2	19.8
Teaching	2.7	2.3	1.9	2.5	2.6	1.9
Consulting	2.6	4.9	17.0	4.0	5.1	4.5
Production/ inspection	10.8	16.4	21.9	15.3	27.3	14.9
Reporting, statistical work, computing	5.8	3.5	4.4	4.2	7.6	2.8
Sales	1.4	3.4	1.4	1.9	3.4	2.2
Other	3.8	0.9	1.3	1.0	1.0	0.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: U.S. Scientists and Engineers: 1988, Surveys of Science Resources Series, Selected Statistical Tables, National Science Foundation, Washington, DC.

6. Graduate work outside of engineering.
7. A mix of two or more of the first six options.

The author has drawn freely from Reference 14 in describing these career paths for engineers.

2.13 THE CORPORATE LADDER

The great majority of engineers are employed by private industrial or business organizations (see Table 2.3). Most of the jobs in engineering are with large corporations. Engineers who work for large companies typically have many career options. The possibilities include the practice of "hands-on" engineering, proposal writing, marketing of engineering services, and upper echelon management.

The immense breadth of corporate activity minimizes the career damage that might result from working in an inappropriate job. The engineer, for example, who finds that by the age of thirty he is bored with the laboratory can quietly move laterally, if he is inherently qualified, into management or sales. No other option available to the graduating engineers offers quite this degree of flexibility and potential for substantial, even radical, career change.

Furthermore, because of the depth and variety of corporate resources, it is possible for the exceptionally promising engineer to climb the corporate ladder while simultaneously working toward post-baccalaureate degrees. Many progressive companies are willing to provide formal university training for young engineers after they have demonstrated their competence and dedication to the firm. Other companies have developed contractual relationships with universities by which employees may take regular courses for university credit in the evenings or during time-off periods during the day. In addition, many corporations perform a broad and ongoing educational function by offering in-house training courses taught by the company's technical staff.

The young engineer achieving his or her baccalaureate degree must realize that there is truly no such thing as "business" and no such genetic entity as "the corporation." Companies, even companies producing and marketing highly similar products, differ as much or more than individual human beings differ.

Some companies project a relatively conservative image. They tend to promote their employees primarily on the basis of longevity with the firm, and they are more concerned with what the employee has learned in the company than with what he or she has learned in school.

To other companies, experience is not a crucial factor, because they are developing new products and new technologies at such a pace that long-term experience can have little value. State-of-the-art knowledge and the ability to apply it imaginatively are more important. In contrast to the experience-based company, such knowledge-based firms often are in a state of constant evolution, generating for their employees a great deal of excitement, as well as many ulcers.

It should be remembered that companies also differ in relatively minor but often personally crucial ways. In one company, the weekly cocktail party is an essential ingredient in the corporate continuum; in another, the public consumption of anything stronger than steam beer is frowned upon. In one company, social groups may be important; in another, outside activities, such as community service, are more valued. One company pays for spouses to go to conventions; another company sends nobody at all. Such wide variations in corporate personality, while confusing to the engineer evaluating the corporate ladder option, are indicative of one of the strengths of this career choice. There is, somewhere, a company for nearly everybody. No matter what your temperamental inclinations, no matter what your interests, no matter what your biases or prejudices, no matter what your preference in clothes and haircuts, there is at least one company—and usually many—where you will feel right at home and be able to work effectively. It is just a matter of finding it.

2.14 THE INDEPENDENT ENTREPRENEUR

Many graduating engineers prefer to work for themselves. Some become consultants, providing engineering services to individual clients and to public agencies. A good way to gain entrance into this activity is to work for three to five years in a corporation, a public agency, or for another, more experienced consultant. That experience will help to build the high level of individual responsibility that consulting engineering firms demand.

If the consulting route to individual entrepreneurship takes a modicum of courage and steadfast determination, then turning your knowledge and competence into capital, and launching a new company—perhaps even right out of college—takes a good deal more. Yet it is done, and done successfully, quite often. Becoming an independent is, without question, one of the most exciting possibilities the engineer has to contemplate. The ultimate goal is to be independent and autonomous, answering to no one but yourself and, of course, your clients.

2.15 EMPLOYMENT OPPORTUNITIES IN GOVERNMENT

Government employment for engineers is available in two ways: you can join the military or you can work as a civilian employee. Many believe that the superior alternative is to join one of the uniformed services such as the U.S. Navy's Civil Engineer Corps or the Army Corps of Engineers.

Because of the nature of the defense establishment, young engineers wearing the uniform have opportunities for immediate and intensive interfacing with ultra-high technologies and state-of-the-art equipment that generally are not present in even the most advanced regions of the private sector. Also, because of the nature of the military establishment, there is far less stress on age, experience, and seasoning than one often finds in the civilian corporation or company. Consequently, the just-out-of-college engineer can move upward and inward with a rapidity that is seldom seen in even the most progressive companies in the private sector.

Moreover, because the military goes about its job without reference to profit-and-loss statements, there is a marked inclination to send promising young engineer-officers back to the university campus for advanced degrees, both M.S. and Ph.D. Indeed, joining the Air Force, Navy, or Army and letting those organizations foot the bill for graduate education at front-rank schools is now a standard route for ambitious young engineers of limited means to follow.

Large numbers of civilian engineers are employed by agencies of federal, state, and local governments. The greatest opportunities for work in government exist for civil engineers.

Civilian engineering positions exist in numerous agencies of the federal government including the Federal Highway Administration, the Federal Aviation Administration, the U.S. Army Corps of Engineers, and the National Aeronautics and Space Administration (NASA), to name a few. Civilian engineers can be found performing research in harbor protection, designing and maintaining facilities on Air Force bases and in naval shipyards, and contributing to NASA's vast and exciting program to explore outer space.

At the state level, engineers are employed in large numbers by state highway agencies and may be found in agencies concerned with port operation, water resources management, and protection of the environment.

At the local level, engineers serve as directors of public works, manage water treatment plants, and oversee pollution control programs.

Engineering positions in government may provide satisfying and interesting work, with the added benefits of secure employment with liberal holidays and vacations and attractive programs of health and retirement.

2.16 ENGINEERING AND SOCIAL SERVICES ABROAD

The service impulse, the urge to improve the quality of life of those less fortunate than ourselves, has special relevance for the engineer. There is profound, bitter irony in the fact that in the Golden Age of Technology, uncounted millions of people nevertheless exist in ignorance and squalor, standing all their brief lives in the shadow of pestilence and death, going to bed hungry and hopeless day after barren day and year after barren year.

The problem is both technological and cultural. Since World War II we have learned the hard way that no technology can be simply picked up and used by a culture that is not already pervasively technological. Moreover, to abruptly dump quantities of hardware on any culture that has been basically rural and agricultural for tens of thousands of years is to invite disaster—instead of strengthening the culture, we destroy it.

Hence the problem of technological transfer is perhaps the most urgent one facing an uneasy world today. It requires sensitivity beyond measure to devise techniques for grafting urgently needed technologies upon ancient cultures in such a way that the culture retains its social, economic, and religious validity, and ethnic integrity. This is the job for the engineer whose command of his or her specialty is balanced by sensitivity, humor, patience, empathy, great social imagination, and a love of people in all the incredibly immense variety of their values, attitudes, and lifestyles.

However, certain cautions are in order. Ancient cultures frequently move at a pace far slower than most Americans are accustomed to; the result, for an American, can be an intense sense of frustration. Moreover, in most countries of the Third World, it is next to impossible to depoliticize the engineering job—there is no such thing as "pure" engineering, and the engineer who is not willing to cope with the local politics of the region would be well advised to abandon this option altogether. Finally, the power of tradition and of traditional ways of doing things must never be underestimated. If the shift to the new and demonstrably more productive technology demands the abandonment of ancient patterns of thought, or centuries-old cultural habits, then it will not likely be accepted.

2.17 THE ENGINEERING PROFESSOR

The academic career option is essentially in two forms. Of the 280 or so departments, schools, or colleges of engineering in the nation, many are straightforwardly academic, campus-centered departments or colleges in just the sense that chemistry, or botany, or English at these same schools are academic departments. That is, the teaching task is primary and central. The engineering professors in these departments and colleges may and indeed generally do research leading to publication—like anyone else, they need to keep themselves on the leading edge of their specialty—but it is understood that whatever research projects they undertake must be fitted in around their classroom responsibilities. In other words, engineering professors at these mainline teaching institutions will generally carry a full teaching load, from 9 to 12 classroom hours per semester, and devote whatever time is left over, after lecturing, grading papers, and advising students, to their research.

In sharp contrast to such mainline, classroom-centered engineering departments and colleges are the institutions where research is awarded a place equal to and sometimes superior to classroom teaching. These are the institutions that pull in literally hundreds of millions of dollars every year in research funding, not only from governmental agencies, but also from the large corporate entities of the private sector as well. The engineering professors at these universities are as committed to teaching and excellence in the classroom as their colleagues at the teaching-oriented institutions, but it is believed that the researching being done may be of such urgency and significance that some relief from teaching responsibilities is often necessary.

Most engineer-professors who pursue their careers at research-oriented universities are extraordinarily aggressive and doggedly resourceful people, temperamentally comfortable in a situation where they frequently have to "wing it," not entirely sure where their next research dollar is coming from. This is not for everyone. Nevertheless, for those who are temperamentally suited to it, the dual life of teacher-scholar and funded researcher can be immensely rewarding, often in ways not available in any other option. Nowhere else can one find the freedom and autonomy for both teaching and research that are one of the traditional rewards of university life.

2.18 GRADUATE WORK OUTSIDE OF ENGINEERING

The person with a Bachelor of Science degree in engineering can move with great propriety from an undergraduate commitment to engineering into such fields as law, business, and medicine; this is a possibility that should never be overlooked by the undergraduate engineer assessing the possibilities of graduate work beyond the first degree. The engineer-lawyer whose client is an organization of farmers intent upon suing an upstream manufacturer for increasing the salinity of irrigation water will know the right questions to ask, will be able to spot fallacies and falsehoods in his opponent's defense, and will be able to deal with expert witnesses in a knowledgeable and authoritative way. Again, the business executive whose undergraduate work is in engineering will be able to approach the technical aspects of the design, testing, production, and marketing of any product with a confidence and authority that colleagues who studied only accounting and public relations in their undergraduate years will not possess. Finally, the medical doctor who can bring his or her engineering

knowledge of relatively simple machines to bear on his study of that most complex of all machines, the human body, will be able to visualize biomedical hardware—pumps, valves, delivery systems—that usually stand well outside the conceptual boundaries of the more traditionally trained physician.

Indeed, the liberal and liberating effects of a rigorous course of study in undergraduate engineering are so pronounced, and so susceptible to generalization, that there is hardly a field of human endeavour into which the person with a B.S. in engineering cannot confidently move after graduation.

2.19 THE MULTIPLE-TRACK, VARIABLE CAREER

In one sense, of course, the above discussion of the six life-options facing most engineers achieving the baccalaureate degree is artificial and somewhat misleading, since it suggests that you must follow one option for life, to the exclusion of all the others. But this is not the case. Life is long, and the growth of the individual cannot be predicted in such a tidy manner. It is easy to imagine a career in which, for the first seven or eight years, you are a hands-on, laboratory-centered engineer immersed in research and development for a large corporation. With that experience under your belt, and some accumulated capital to go on, you abandon the corporate ladder and the big city, spending the next five or six years as an independent entrepreneur, running your own three-man consulting firm in a small town. Your reputation as a consultant grows with the years, however, and you find yourself occasionally abroad, serving as a technical advisor to foreign governments and corporations. You discover, a little to your surprise, that you have a taste for travel, a talent for languages, and a growing interest in foreign cultures, and so you finally accept a post offered by the government of one of the developing Third World nations. This in turn leads to American contacts at the embassy level that land you, after a decade or so, in the Pentagon as an advisor on military and economic aspects of your specialty. You round out your career with a return to the corporate ladder, only this time at the top: You accept a high-level managerial position with the very company you started with so many years ago. You retire finally from the position with honor and distinction—only to set up yet another consulting firm, this time solo, just to keep your hand in during the Golden Years. The moral of the story is that no one can predict the course his or her life will take, and it is a lot more fun if you do not try to do that.

INITIAL CAREER PROFILES

In an attempt to provide some ideas of what engineers do initially when they graduate with a bachelor's degree in engineering, Dr. David Irwin (*15*) contacted a number of graduates throughout the country who had been out of school less than 18 months and asked them to briefly describe their initial career paths. Their responses are summarized in the following paragraphs and are included with the permission of Dr. Irwin and the IEEE Press.[1]

2.20 CHEMICAL ENGINEERING GRADUATES

When Jerry graduated, he went to work for a paper mill in the southeastern part of the country. He is a process engineer. He works in a technical group comprised of six engineers. Their job is to get as much production as possible out of the mill. Projects are assigned individually, and he is responsible for his tasks. The company has only one mill, and therefore there is no travel associated with his job. He typically works 40 hours per week. Jerry likes his job and plans to stick with it. For recreation, he is an avid tennis player.

Monica is a process engineer with a large oil-refining company. She works with about a dozen other engineers, but is the only process engineer in the group. Her job is to ensure that the wastewater treatment facility meets the permit requirements for wastewater discharge. Most of her traveling is involved in taking continuing education courses. She typically works about 45 hours per week. She enjoys her work and plans to move around within the company to increase her experience. In her spare time, she likes to go to the beach.

Anthony graduated with a very high GPA. He came from a poor family but had excellent grades and was practically put through school on scholarships. He worked at summer jobs to supplement his income while going to school. His last summer job was with a major drug manufacturer, and he found that he really liked doing creative work. So he opted to go to graduate school and is currently attending one of the most prestigious universities in the country.

Harry is a sales engineer for a large chemical company that manufactures a large array of chemicals. He spends many hours on the road. Harry may spend as much as a month at a customer's location, running tests and trials in order to sell his product. He normally takes some technical support with him in the form of two other engineers. He typically works about 60 hours per week. He hopes to either move up in the management of his company or start his own business. In his spare time, he likes to play bridge.

Ginger graduated from the university with a high GPA. Although she planned to enter engineering practice, she had always had in the back of her mind that perhaps she would like to be a medical doctor; therefore, she decided that if she was ever going to try it, the best time would probably be right away. She entered a medical program in the Southwest and is doing very well. Although she misses engineering, she believes that she will be able, one day, to combine her knowledge of both areas in a viable career. She claims that she does not have a lot of spare time.

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2.21 CIVIL ENGINEERING GRADUATES

Bridget graduated from the university with a very high GPA. She is an assistant project director with a state department of transportation (DOT). She is out on the job site (e.g., a bridge construction project), in a hard hat and boots from 7 A.M. to 4 P.M. It is her job to supervise the state workers on-site and the other construction companies that work for the DOT. She is personally responsible for the construction to be done correctly. She travels a lot locally and typically covers the entire county in which she lives. She normally works 40 hours per week and is paid for any overtime. In her spare time, she has been involved in judging science fair projects in the local school system, and she likes to swim. Her plans for the future involve going to graduate school.

George's title is that of civil engineer. His company is a small engineering firm with about 150 people (25 percent of whom are engineers) that does engineering work in the electrical, architectural, and mechanical areas. George's specialty is the design of wastewater distribution systems. He normally works in a team on big projects and if the project is primarily one of a wastewater nature, he will act as the project leader. If the project is small, then he will work alone. He travels on average about two days per month and works about 50 hours per week. His future plans involve going back to school to get an M.B.A. He is an avid golfer and consistently shoots in the high 70s.

Amy is project engineer with a civil and environmental engineering consulting firm. She is involved in what she calls "hard-core design." She designs wastewater treatment facilities and is also concerned with the environmental impact statements for landfills and storm water systems. The company has about 150 employees, and on small jobs she typically works with one other engineer. Her job involves both office and field work. A lot of her office work involves computer modeling for water transmission systems. The amount of traveling she does depends totally on the project and, in some cases, can involve quite a bit. She typically works about 50 hours per week. She loves her work and plans to stay with it. She does, however, want to get her Professional Engineer's license and move up to project manager. In her spare time, she exercises a lot and participates in church activities. At the time of the contact, she was planning a wedding and was totally immersed in that.

As Charlie went through his undergraduate program, he decided, based on some of his course work, that he wanted to work in the environmental engineering area. The school that he attended did not have a program in environmental engineering at the undergraduate level, so he decided to pursue a master's program in that area. He is currently about halfway through the program at a major university, working as a graduate teaching assistant. He is enjoying his studies and his teaching. He is paid a modest stipend to teach, but it is sufficient for his needs. He is looking forward to graduating in about a year and entering the workforce in the environmental area.

Clifford works for a small company (about 100 employees) that sells mixtures for concrete. He is in technical sales and is a lone ranger in that he works by himself. He does have some service people who back him up on occasions when their help is needed. He travels anywhere from 2000 to 3000 miles per month within the state where he lives. In his normal routine, he works about 55 hours per week. Clifford's goal is to have a business of his own. In his spare time, he likes to hunt, fish, and play tennis.

2.22 ELECTRICAL ENGINEERING GRADUATES

Lisa used the cooperative education program to get through school. Although she did her co-op work with a government contractor, when she graduated from school, she went to work for a major electric utility. She liked her co-op work and believes that it gave her a good idea of what to expect when she began working full-time in the real world. She designs the control systems, which employ programmable logic controllers, for the generation of steam in fossil-fuel power plants. She normally works by herself but has a support group that works with her on certain projects. She does the design in the office and then the installation is, of course, done in the plants. She will typically travel four to five days per month. She plans to get as much experience as possible in the design and instrumentation area and is currently not thinking beyond that point. In her spare time, she enjoys camping and traveling.

Joe was a co-op student while in school and maintained a high GPA. His co-op assignment was with a local telephone company. His father is a physician and could have easily paid for Joe's education, but did not do so because he believed that Joe would get more out of school if he worked his way through. During his senior year, Joe took an elective course in image processing and became fascinated with the subject. He decided that he would like to go to graduate school in that area. He was interested in applying image processing to medicine, with techniques such as magnetic resonance imaging (MRI). Joe is now a graduate research assistant at a major university, working with a professor whose research is in the image processing area. When he has a break in his schoolwork in the winter, he loves to snow ski and can do so with ease. In the summer, he likes to fish.

When Ian graduated from the university, he went to work with a friend of his father's. He has known the man most of his life. He is in the technical sales area and works as a manufacturer's representative. Ian covers an area of approximately a 200-mile radius, including two relatively large cities. He typically works with electronic measurement equipment and goes to customers in his area to demonstrate it. He does a lot of traveling and typically works about 55 hours per week. He enjoys hunting and fishing in his spare time and hopes to learn enough in his work to start his own business.

Sam's education in the area of electrical engineering was unusual from the very beginning. His father had a small law firm in a relatively unpopulated Midwestern area. His father wanted Sam to enter the law firm and eventually take it over when his father retired. Sam was interested in doing just that. So why did Sam go into electrical engineering if he was planning on a career in law? The answer is simply that his father had told him that he would need an undergraduate degree in some area before he could enter law school, and he felt that a degree in electrical engineering would teach him to think critically and analyze problems in a systematic manner. So Sam is now in law school at a different university and planning on joining his father upon graduation.

Fran's title is that of engineer, and she works for an engineering firm that derives the majority of its business from government contracts. She is involved in the design of infrared weapon systems and in her work uses a wide variety of software programs. She typically works by herself; however, because of her co-op experience gained while going through school, she also heads up a group that is involved in training other people in the company. Her traveling is confined to attending continuing education courses that keep her abreast of new technology in her field, and this traveling averages no more than one or two days per month. There are times when she will work 70 hours per week (that includes 13 hours per day on the weekend) while she is involved in supervising other contractors who work through her company for the government. She has just had a baby and is interested in obtaining an aerobic instructor's certificate. If she can get this certificate, she can teach aerobics after working hours, and the place where she would teach has a day care center where she can leave her child. In the future, she would like to pursue a master's degree in electrical engineering.

2.23 MECHANICAL ENGINEERING GRADUATES

Juan works for a mechanical contracting firm, and his title is that of engineer. The firm is small and does about $15 million worth of business per year. Juan estimates that his time is divided as follows: 70 percent of the time he is involved in estimating the cost of a job (i.e., bid specification), 10 percent of his time is spent in purchasing and making sure that equipment arrives at the job site on time, 10 percent of his time is spent in design, and the remaining 10 percent is spent in the CAD area with shop drawings. He normally works by himself, and on large jobs he is the key person responsible for all the air distribution and duct work. He enjoys what he does and feels that he is exposed to a wide range of design firms from all over the country. He does very little traveling and typically works about 50 hours per week. He plans to get his Professional Engineer's license and hopes to one day be a partner in the firm. For recreation, he likes to play tennis.

Teresa is called a general engineer and works with one of the U.S. government laboratories that does research on wood for paper products. She is involved in testing and analyzing the mechanical properties of paper, specifically its coefficient of friction. Her work impacts paper manufacturers and the printing industry. The laboratory has about 300 people, and she works in a group of about 10 people that moves from product to product to solve various problems. She typically works under one of the more senior engineers and normally works about a 40-hour week. She does very little traveling in her job, but what traveling she does is confined to continuing education courses and conferences. Her job is a fixed-time contract and will end after a three-year period. She wants to move to a position where she can do work in heating, ventilating, and air conditioning. At present, she is taking a correspondence course in preparation for taking the Fundamentals of Engineering exam; later, she would like to obtain a Professional Engineer's license. In her spare time, she is involved in all types of recreational activities.

Adrienne is a boiler performance engineer with a utility company. She travels throughout the company's service area testing boilers in power plants to make sure that they meet the clean air requirements. She is one member of a team of four engineers that attempts to balance efficiency and emission control. The engineering department of the company has hundreds of engineers, and there are groups such as the one that she is in whose jobs include testing turbines. Depending on the type of job in which she is involved, she may be the lead engineer or she may act in a support capacity, She does a lot of traveling. She is away from home, on average, about three months out of the year. It takes about three to four weeks to do a test, and therefore she is gone for this period. However, she is home on the weekends. Adrienne typically works about 40 hours per week unless they are very busy, in which case she may work 50 to 60 hours per week. She enjoys what she is doing and plans to stick with it, learning all that she can about the business. She is an outdoors-type person and enjoys playing basketball. At the moment, she is planning a wedding, and that activity is taking up most of her time.

Ryan works with a small engineering firm that has about 30 employees. The company is owned by a much larger company that does environmental engineering work. Ryan is involved in abatement and remediation work. He oversees the removal of such things as asbestos, PCBs (polychlorinated biphenyls), heavy metals, and aromatic hydrocarbons. Although he works in a team and reports to a project supervisor, he is responsible for his part of the project. In his work, he follows the job and relocates wherever the job is; that is, when he finishes one job, he moves to another. He normally works about 50 to 55 hours per week. At present, he has no plans for the future. He likes what he is doing and feels that he is too young to worry about planning too far ahead. He likes the outdoors and spends most of his spare time hunting and fishing.

Brad worked his way through school as a diesel mechanic. He worked for a very large trucking firm that had hundreds of tractors and trailers. When he received his degree, he was made the director of maintenance for the firm. As such, he is responsible for keeping all the rigs running. He also works very hard to control maintenance costs and keep all the electronics on the trucks in working order, and is the individual who is responsible for matching the most efficient tractor to trailer when purchasing new equipment. In addition, he is the person they call if there is an accident and diesel fuel is spilled. He supervises about 70 technicians who work in a number of depots over a multistate area. He typically makes about one trip per month in his supervisory position and attends professional meetings that deal with the trucking industry. He normally works about 45 to 50 hours per week, unless there is a diesel fuel spill somewhere in the country. He has passed the FE exam and is currently working toward his Professional Engineer's license. He plays golf with customers, and in his spare time he is a member of a softball league.

2.24 BIOMEDICAL ENGINEERING GRADUATES

When Paul was in high school, he thought that he might like to be a medical doctor. So he asked some of the physicians in his hometown if he could go with them while they visited with some of their patients. They were happy to accommodate his wishes, and, as a result, Paul decided to pursue a career as an orthopedic surgeon. During a visit to the university he planned to attend, he found that they had a program in biomedical engineering. He entered the program and took his elective courses in biomechanics. He is now in medical school pursuing a program in orthopedic biomechanics. He loves his studies, but has little or no time for anything else.

Curtis had always been interested in medicine, but did not want to practice as a medical doctor. He learned that the university had a program in biomedical engineering, and so he entered that program with the hope that he would be able to work for a drug company. When he graduated, he accepted a job with a large drug manufacturer and is currently involved in the development of delivery systems for genetically engineered drugs and screening tests that determine the applicability of this type of drug therapy. He enjoys his work and normally works a little more than 40 hours per week. His passions are skiing and backpacking, and he does these things every chance he gets.

2.25 COMPUTER ENGINEERING GRADUATES

Because Eileen's father was a computer systems programmer, she had been exposed to computers for a long time prior to entering the university. She decided that she wanted to pursue a similar career, and therefore she entered a program in computer engineering. While in school, she was much more interested in software than hardware and, as a result, when she graduated, she took a job with a major defense contractor as a software engineer. She does programming in a real-time environment for a weapon system under development for the military. She normally works about 40 hours per week unless there is a design review, in which case she may work overtime in preparation for her presentation. She enjoys playing golf in her spare time.

Keith was a little older than most students when he entered a program in computer engineering. He joined the Navy upon graduation from high school and worked as a radio operator. He then went to work for a major electronics manufacturer as a commercial electronics technician. When he graduated from the university, he went to work for a government contractor. He is involved in the development of a Windows-based automated testing system that controls complex communications test equipment and shipboard radio equipment. He has been able to replace some outdated equipment with some of the modern technology that is capable of efficiently handling the task with cheaper, more reliable equipment. His work schedule typically requires about 40 to 50 hours per week. He enjoys water sports and owns a small sailboat that he uses every chance he gets.

2.26 ENVIRONMENTAL ENGINEERING GRADUATES

Tim's family was always concerned about environmental issues, and he guesses that it was this influence that guided him toward a career in environmental engineering. When he graduated from the university, he went to work for a consulting firm that specializes in municipal wastewater treatment. He was paired with an experienced engineer involved in the design and construction of a new wastewater treatment system. In this capacity, he works with both the laboratory technicians to determine the characteristics of the wastewater and the state to obtain a discharge permit. He is also part of a team that must decide what types of processes must be linked together to achieve the level of treatment desired at the cheapest cost. His work schedule is approximately 45 hours per week, sometimes longer when he is in the field. Tim is really into backpacking and does it every chance he gets.

When Sheila entered the university, she was not really sure what curriculum she would follow. However, one of her girlfriends was going into environmental engineering, and so Sheila thought she would look at that curriculum closely as a possible career path. After talking to some of the professors in that area, she decided to enter that program. When she graduated, she took a job with a state agency that is involved in permitting activities for industrial and municipal wastewater treatment systems. Sheila calibrates a waste load allocation model of a receiving stream in order to set discharge limits for a proposed wastewater treatment system. She rarely works overtime, loves her job, and spends her free time exercising and working as an aerobics instructor.

2.27 INDUSTRIAL ENGINEERING GRADUATES

Melanie's father was an industrial engineer, and he had convinced her that this would be a good career path for her. After graduation, she went to work for a large semiconductor company on the West Coast. She works in a team that is designing the layout of a manufacturing process. They are concerned with efficiency and the control of production and materials. Melanie is personally responsible for the ergonomic aspects of the jobs and must ensure that each job is safe and that any risk of injury is removed. She enjoys her job and typically works about 40 to 50 hours per week. In her spare time, she likes to play tennis and has joined a health club where she can play and meet other people with similar interests.

When Allen graduated from the university, he joined a company that manufactures snack foods. He is on a one-year training assignment as a production supervisor. In this capacity, he is responsible for all aspects of the production line, including dealing with personnel problems, scheduling the materials, and maintenance. He will soon complete this assignment and looks forward to going into some engineering function with the company. Although Allen works a 40-hour shift, his work normally extends far beyond this time due to problems that invariably arise. When he has time to do so, Allen is an avid bicycle-racing enthusiast.

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