SECOND EDITION

# *SAFETY AND HEALTH FOR ENGINEERS*

**ROGER L. BRAUER,** Ph.D., CSP, PE

*Tolono, Illinois*

WILEY-INTERSCIENCE

A JOHN WILEY & SONS, INC., PUBLICATION

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# PREFACE

Since the first edition of this book, some things have not changed and others have. Today, engineers still have a moral, legal, and ethical responsibility to protect the public in professional practice and in design of products, buildings, processes, equipment, work, and workplaces. The importance of safety in engineering education remains a concern for most engineering degree programs. The need for safety specialists to understand basic technical fundamentals essential in hazard recognition, evaluation, and control continues. As a result, there is still a need for this book.

The laws, regulations, standards, and standard of practice in safety and health continue to change on a regular basis. As soon as a book is complete or updated, it is likely to be out of date in certain regulatory areas. The reader should recognize this type of change and consult government and voluntary standards to ensure compliance with current requirements.

Technology continues to change. Computer technology has changed the toolbox for nearly every professional field, and it impacts safety practice as well. Since the first edition was published, the Internet has become an integral part of professional practice, business and business transactions, and many other elements of daily life. Although the explosion in availability of information continues, one must be able to sort out valid, quality information and reliable information sources from those sources that are not. It is far easier today to find information as well as misinformation on a wide variety of safety issues.

The overall field of safety has changed. One significant trend is the continued growth in education of those practicing at the professional level. More individuals than ever who specialize in safety have advanced degrees. At the same time, many employers have achieved significant improvements in safety performance by moving safety knowledge and skills deeper into their organizations and workgroups. There seems to be a growing interest among people from other areas of work experience in finding a professional home in the broad safety field. Another trend is the rapid convergence of several related areas of practice. Two decades ago, safety, industrial hygiene, environmental science and engineering, environmental health, ergonomics, fire protection, and other areas of practice often were isolated from each other. Today, many of these have converged into a single organizational unit for an employer, and many individuals—regardless of their original backgrounds—have responsibility for many of these areas simultaneously. The overall impact is a change in what safety and health specialist do.

The original goal for this book was to help engineers and others gain a broad, quick overview of safety and health practices and to identify some of the detailed resources that may provide expanded help with applications. One of the most valued results of having written this book in the first place is having people who I have never met express appreciation for the assistance it provided them in their professional development. Many have told me that it helped them to understand what safety and health practice is about. It is rewarding to know that a personal project has assisted others professionally.

In completing the update, there are many to thank who may have contributed in some way to the insights offered among the revisions and who pressed me to keep working to complete the revision. I also want to thank my family for their continued support and for tolerating the time often stolen from family activities to make room for the revision effort after abnormally long but typical work weeks.

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PART I

# INTRODUCTION

**THIS SECTION** of the book identifies the technological foundation of safety engineering, summarizes its history, and outlines some fundamental concepts for safety.

CHAPTER 1

# THE IMPORTANCE OF SAFETY AND HEALTH FOR ENGINEERS

## 1-1 INTRODUCTION

### Technological Change

Engineers have played a major role in technological advancements that have created many changes for mankind. Some advancements have improved society, some have been detrimental. Some have aided life, others have created new economic, social, political, environmental, or safety and health problems.

One noteworthy change brought about by technology is faster and more efficient travel. Not long ago, people traveled approximately 8 km/hr or less either walking or via animal-powered conveyances. Automobiles made travel approximately 10 times faster than that, airplanes 100 times faster, and rockets more than 1,000 times faster. A horse-drawn wagon could carry a 1- or 2-ton load. Today, a 200-car freight train can carry 20,000 tons, and supertanker ships carry similar or larger loads.

Communication and electronics technologies continue to shrink the world and change lifestyles. The Pony Express moved only small pouches of information at one time. Today, there are many communication satellites in orbit, transmitting millions of bits of information every second. At least 95% of American homes have a television set. Nearly half have more than one DVD player. Children spend an average of three and one-half hours per day in front of a TV set; adults average more than 4 hours per day. One used to associate a telephone with a place, whereas today one associates a telephone with a person. The Internet and personal computers offer electronic mail and access to specific information sources around the globe at any time.

Technology not only has increased the flow of information, it has increased information density. A printed page in a book contains approximately 450 words. A 600-page book contains approximately 270,000 words and occupies approximately 70 cubic inches. A DVD can store nearly 1.5 million pages of text. A small memory stick can store the equivalent of 1,000 books in less than 1 cubic inch.

Because of technology, the number of materials and substances known to humanity has increased rapidly. Today there are approximately 5 million substances listed in the *Registry Handbook*.[1] Nearly 100,000 chemical substances are now in use, with several hundred new ones entering the marketplace each year.

Advances in medicine, supported by new technology, have extended human life. In the early stages of the industrial revolution, life expectancy for the working class in Manchester, England, was 17 years; for the gentry, it was roughly 35 years. Today the life expectancy of American males is more than 72 years; for females, it is nearly 80 years.

*Safety and Health for Engineers, Second Edition*, by Roger L. Brauer

Diseases that were once a major threat, such as smallpox, typhoid, cholera, bubonic plague, diphtheria, tuberculosis, and polio, are now well under control. Vaccination, improved treatment, wonder drugs, and sanitation made these advances possible. And now we are beginning the age of biological medicine, with diagnosis from DNA analysis and biological growth of substances, tissue, and perhaps even organs for treatment.

Aided by advances in medicine and improved standards of living, the world's population has risen from approximately 0.3 billion in 1 A.D. to 1.1 billion in 1850 and to more than 6 billion today. The increase is creating a new demand on available resources in the world. For example, the per capita energy consumption in the United States is more than $350 \times 10^6$ BTU annually.

Manual labor has given way to industrialization and automation. Production rates have increased rapidly as a result. The industrial production index, which represents the rate of industrial output (equal to 100 in 1967), grew from 42 in 1950 for transportation equipment to 140 by 1979. For chemicals, the index grew in the same period from 26 to 208.[2]

## The Risks

Although life has improved and has been extended, citizens of the United States pay a high price for their high-technology lifestyle. Each year, there are more than 100,000 accidental deaths and nearly 10 million disabling injuries. The cost of all accidents in the United States is approximately $600 billion annually, excluding some indirect costs and the value resulting from pain and suffering. Accidents are the fifth leading cause of death. For those aged 65 or older, the accidental death rate is increasing. Only heart disease, cancer, stroke and chronic respiratory disease exceed it. For the total population, the two leading causes of accidental death are motor vehicles and falls. Nine times more workers die accidently off the job than at work. The accidental death rate in the United States has declined from approximately 85 to 90 deaths per 100,000 persons in 1910 to fewer than 35 today.[3]

Not only has technological change introduced new methods, materials, products, and equipment into use by society, but also new hazards. For example, electricity replaced gas and oil lighting. Electricity may be less hazardous than gas and oil lighting; however, it is identified as the cause of one of every seven fires and produces roughly 100 electrocution deaths each year.

Another example of a new hazard is asbestos. In the 1930s, asbestos became a widely used material for thermal insulation, roofing, brakes, and other applications. A 1978 estimate by the federal government said that 8 to 11 million workers had been exposed to asbestos. Of those, one million were significant to the point that half of these individuals could expect to die of cancer in the next 30 years. Some believe that this is an overestimate and does not explain the full story. It does illustrate that hazards associated with new technology are sometimes widely distributed in society.

The automobile arrived at the end of the nineteenth century. Today, there are approximately 1.5 motor vehicles per American household. The use of these vehicles now results in roughly 45,000 traffic deaths and 2 million disabling injuries each year in the United States.

## Society's Response

Society has responded to the safety and health risks placed on them by technology, primarily through regulation and litigation. Federal, state, and local governments have passed many laws and regulations dealing with safety and health issues. More than 15,000 new laws are passed each year. Approximately 10% or more of these involve safety and health.

The 1960s and early 1970s saw the creation of several federal safety and health agencies and the emergence of others through restructuring of some existing federal organizations. Each of these created new regulations. Counterparts often have appeared at state and local levels and produced additional regulations and standards.

Society has turned to the courts to recover losses from injury and damages for pain and suffering. According to congressional estimates, there are between 60,000 and 140,000 product liability claims filed each year. In addition, legal interpretations place a greater burden on the manufacturers and sellers of products to minimize the risks to their users. As a result, product liability insurance rates have grown. Tort reform efforts seek to limit liability claims in size and frequency.

Although death and injury rates are holding steady or are on the decline, the public is not fully satisfied with the protection offered by government and industry. In one opinion survey,[4] public respondents rated the job being done by the federal government, the business community, and state and local government to make society acceptably safe. The differences among the ratings for the three groups were small. Overall, approximately 25% to 33% of the public said these groups did a very good job, 50% said they were doing only a fair job, and 15% to 23% reported they were doing a poor job.

The survey results also suggest that the public continues to look to government and society for protection from technological risks. One of every five public respondents believed that "no matter what risks an individual takes, there should be no personal economic penalty; society as a whole should bear the cost." In another survey,[5] 75% of the respondents wanted government to cut back in size. However, nearly 50% of the people surveyed believed that the government was doing less than it should to regulate major corporations in areas like product safety and other matters that have to do with protecting the public. Twenty-two percent of the respondents believed that the federal government was doing more than it should and 27% said the government was doing the right amount.

People said they want to exercise control and choice in the risks they face. The public does not always see eye to eye with industrial and government leaders regarding technological risks placed on them. In the first survey mentioned above, more than half of the respondents wanted a choice in making tradeoffs between risk and cost. One question asked whether the higher risk of fatal accidents with small cars was worth the savings from fuel and initial cost. Almost 50% of the public said it was not. In contrast, only 11% of the top corporate executives and 15% of the congressional representatives included in the study shared the same view. More recently, the public love affair with large cars has shifted to minivans, sports utility vehicles, and trucks.

### A Closer Look

Technology has brought new things to modern life. We live better lives through chemistry, electricity, transportation, electronics, and communication. Society has accepted the benefits, but not all the risks. It has placed new demands on engineering and other professions to reduce safety and health problems.

## 1-2 OCCUPATIONAL SAFETY AND HEALTH

According to National Safety Council statistics, there are approximately 4,500 work-related deaths each year, with a death rate of more than 3 per 100,000 for all industries.

Annually, there are more than 3.5 million injuries involving one or more days away from work. The total cost in lost wages, medical expenses, insurance, fire losses, and other indirect costs associated with these work-related accidents is more than $150 billion annually. This figure does not include business interruption costs. Workplace injuries result in more than 100 million lost workdays each year. Each worker in the United States loses approximately two days each year from job-related accidents.

Since the 1930s, when such record keeping began, the highest number of work-related deaths occurred in 1937: 19,500. However, estimates for earlier years projected a peak of 35,000 deaths in 1913. In general, the trend in recent decades has been toward fewer worker deaths and a lower work-related death rate. At the same time, the number of workers has risen.

Death, injury rate, lost work days, and other statistics do not distinguish job-related injuries from job-related illnesses. It is often very difficult to establish that an illness is job related. Some illnesses have a long latency period between exposure and onset of disease. Workers may have had off-the-job exposures to health hazards, may have had exposure on different jobs, or may have changed jobs. Some employers are reluctant to report occupational illnesses, and many employees and physicians fail to recognize a disease as being job related. These factors suggest that the preceding statistics about worker deaths and injuries may be underestimated.[6]

Accurate estimates of the ratio of job illness to job injuries are hard to find. For federal employees, there are roughly four job illnesses reported for every 100 job injuries. A study cited in a government report on occupational diseases[7] listed the causes of occupational disabilities: approximately one third are caused by job injury and two thirds by job disease. Estimates say that lost earnings resulting from disabling occupational diseases cost more than $11 billion in 1978, and the cost is significantly higher today. Death, pain, suffering, and other intangibles are not included in the estimate.

There are other factors to consider about long-term trends in safety records. There are continual changes in the injuries and illness that are recognized under workers' compensation. These changes influence which incidents are included in records. For example, silicosis was not compensable until the 1940s to 1950s. Formerly, hernia injuries were recognized as job-related when the pain was so severe that workers could not work. Today, hernia symptoms do not have to be as obvious to achieve compensation. We now recognize cumulative trauma injuries as work related and compensable. In the early 1980s, many ergonomics-related injuries were not compensable. The shift in the definition of compensable and job-related injuries may account, in part, for the inability to reduce the work-related injury and illness statistics as much as we would like.

The source of accident, injury, and illness data from industries often is derived from the larger companies that have organized safety programs and organizations. It is not uncommon to find an order of magnitude difference in accident statistics within an industry when all types and sizes of companies are considered. When only a portion of an industry is the source of data, and if this portion is comprised of the better companies in terms of accident records, the actual record may be quite different. The real statistics may differ from published or reported statistics.

Although great progress has been made in occupational safety and health, the toll in terms of dollars, lives, injuries, and illnesses is still high. The statistics often overlook the personal impacts on the individuals and their families.

## 1-3 CONSUMER PRODUCTS AND HOME ACCIDENTS

Accidental death, injury, and illness at home and from consumer products is also a large problem. Many accidents in this group go unreported. The National Safety Council estimates there are roughly 12,000 deaths and 2.9 million disabling injuries annually caused by accidents at home. The death rate for home accidents, now approximately 1.5 per 100,000 persons, and the number of deaths annually have shown a slight decline over the years. The total cost of home accidents, lost wages, medical expenses, fire losses, and insurance administrative costs is roughly $135 billion per year. Some indirect costs are not included in this estimate.

Many home accidents involve consumer products, although all accidents involving consumer products do not occur at home. In 1970, the National Commission on Product Safety attempted to determine the scope of the safety problem associated with consumer products. In their final report,[8] the Commission estimated that there are approximately 20 million injuries at home associated with consumer products each year. Also, consumer products cause 110,000 permanent disabilities and 30,000 deaths annually. These data exclude injuries and deaths associated with foods, drugs, cosmetics, motor vehicles, firearms, tobacco products, radiological hazards, and certain flammable fabrics. The Consumer Product Safety Commission tracks product injuries in hospital emergency rooms through the National Electronic Injury Surveillance System. Data from 1973 suggested that more than 6 million product-associated injuries occur each year.[9]

Today, injury and death from firearms has become a public issue. Individuals and local governments use the courts to make firearm manufacturers liable even though the right to bear arms is protected by the Second Ammendmen.

## 1-4 TRANSPORTATION

Losses from transportation accidents are also very large. Transportation includes motor vehicles, aircraft, railroads, and waterways. By far the greatest cause of accidental death is motor vehicle accidents. Each year, nearly 50,000 people die in motor vehicle accidents and more than 2 million sustain disabling injuries. The overall death rate in the United States from motor vehicle accidents is presently approximately 15 per 100,000 persons and 1.6 deaths per 100 million miles traveled for the 240 million registered vehicles. For drivers in the 15- to 24-year old age group, the death rate is nearly double that of the total population. Although little attention has been given to the death rate from vehicles while on the job, some studies suggest that 25% to 33% of all job-related deaths involve motor vehicles.

The population death rate for air transportation is roughly 0.5 per 100,000 persons. There are some differences between general aviation and commercial aviation. The National Safety Council reports a death rate of approximately 16 per 100,000 persons for general aviation and 0.1 per 100,000 persons for commercial aviation. The National Transportation Safety Board estimated that general aviation had 3.3 fatalities per 100,000 hours of flight, whereas commercial aviation had 5.1 per 100,000 hours.

Over recent decades, there has been a decline in railroad passengers and railroad employees. Over the same period, there has been a decline in railroad deaths and injuries. Each year there are roughly 1500 deaths and 20,000 injuries associated with railroad accidents. Approximately 60% of the deaths and 15% of the injuries occur at rail–highway grade crossings. Other railroad accidents, such as derailments, result in explosions, fires, chemical releases, major property and environmental damage, and legal claims. For example, in the mid-1970s, a 40-car derailment occurred in Florida, apparently caused by vandalism. It resulted in a chlorine tank car leak that killed occupants of an automobile traveling on an adjacent highway and caused other injuries. Resulting liability claims totaled more than $200 million, whereas the small railroad company had assets of less than $7 million.

The U.S. Coast Guard reports that more than 1,500 boating accidents occur each year. Here, too, a major accident can result in large losses, not just death and injury. For example, in May 1980, a freighter rammed the Sunshine Skyway Bridge in St. Petersburg, Florida, ripping out a 1,400-ft section. Thirty-one people died as their vehicles plunged 140 ft to the water below. Authorities reopened the rebuilt bridge after seven years of diverted traffic that impacted businesses and added travel time and expenses for many thousands of people.

## 1-5 ENVIRONMENTAL PROBLEMS

It is difficult to assess the impact of air and water quality on human safety and health. Even when it is known that a substance affects humans, it is difficult to prove that a disease or illness is caused directly by exposure to it. The expenditures made to reduce air and water pollution are assessed more easily. The Environmental Protection Agency estimated that the annual cost for 17 major industries to comply with the Resource Conservation and Recovery Act of 1976 was $750 million.

Another aspect of the environmental problem is the scale and cost of cleanup. Estimates say that in 1980, industry generated 60 million tons of hazardous waste as acids, solvents, oils, caustics, explosives, and other forms. The Environmental Protection Agency estimated there are 30,000 to 50,000 hazardous waste sites in the United States. In 1980, Congress established a $1.6 billion Superfund for site cleanup. In late 1985, the Superfund was extended for five years and an additional $7.5 billion. This funding resulted in cleanup for only a small portion of the known sites.

The costs for claims and for cleanup of a particular site can be very large. Approximately 20,000 tons of waste, made up of more than 80 different substances, were buried at Love Canal in New York. By 1981, $36 million, or approximately $1.00 per pound, were spent in cleanup, relocation of residents, health and environmental testing, and other expenses. This does not include most health expenses, the cost of suffering, and much of the depreciation in real estate values. Nearly $3 billion in lawsuits were filed by 1980. Reported costs do not include most legal settlements.

## 1-6 SIGNIFICANCE FOR ENGINEERS

For a long time, society has sought to protect itself from risk. One means in recent times has been through laws requiring registration or licensing of professions, including engineers. The one justification for engineering registration laws is "protecting public health, safety and welfare." This concept assumes that those who appropriate education and experience and are able to sit for and pass an examination are qualified to provide the protection expected by the public. The public expects engineers to protect them against unnecessary and undesirable risks, particularly those brought on society through technological advancement and change.

Spectacular failures erode public confidence in engineers. Examples include the collapse of the Tacoma Narrows Bridge near Tacoma, Washington, in 1940; the March, 1979, nuclear accident at Three Mile Island near Middletown, Pennsylvania; the chemical waste tragedy at Love Canal in Niagara Falls, New York, in 1978 through 1980; the toxic chemical release in Bhopal, India, in December, 1984, that killed approximately 2,500 people and injured thousands more. A later example, witnessed on live television around the world, was the spectacular Challenger space shuttle accident at Cape Kennedy, Florida, on January 18, 1986, and more recently the Columbia space shuttle reentry accident on February 1, 2003.

The National Council of Examiners in Engineering and Surveying (formerly the National Council of Engineering Examiners) surveyed practicing engineers to find out what they do on their jobs. They found that nearly all engineering disciplines and all kinds of engineering jobs included significant responsibilities for safety and health.[10]

Some have claimed that engineers do not know what they are doing when it comes to health and safety. They point to the fact that professional engineering examinations in most states do not include, or include very few, questions dealing with safety and health. They also note that most engineering curriculums do not include safety and health courses. Many engineering programs incorporate safety and health issues into capstone design projects.

Engineering schools and the engineering profession are becoming more aware of the safety and health challenge. One group of design educators states: "Through the combined voices of society, the government and the courts the message to the industrial/technological community is clear. Consumer groups, regulatory agencies and the law of strict liability all demand that unreasonable risks be eliminated from the interaction of technology with society. The design engineering educator can no longer overlook the fact that the network of regulations, standards and litigation as it has evolved in recent years represents an important set of criteria for design that are added to the traditional constraints of function, cost, manufacturability and, marketability."[11]

At the 1986 National Congress on Engineering Education, representatives from engineering societies passed resolutions about educational requirements for engineers. The resolutions included recommending that training in safety and health be strengthened and that design constraints, such as safety, are essential in engineering courses.[12] These recommendations led to modified accreditation criteria in 1987 for all engineering programs in the United States. The criteria now require that knowledge about engineering practice must include an understanding of the engineer's responsibility to protect both occupational and public health and safety.[13]

Recently, the National Safety Council added a program called the Institute for Safety Through Design to affect engineering design. Its goal is to elevate safety in the design of products, processes, equipment, and vehicles.

Engineers do have an important role in reducing risks placed on society by modern technology, its products, and its wastes. Although engineers cannot bear the total blame for safety and health risks, engineers are able to help reduce them to levels acceptable to society.[14] In planning, design, operations, maintenance, or management activities, engineers should be able to recognize hazards and implement controls for them. Engineers should know how to eliminate, reduce, or control safety and health risks within their sphere of responsibility. Every engineer must know when and how to use other professions, including safety professionals, in analyzing and reviewing their procedures and design decisions. Every engineer needs to know when to say, "I don't know; I need other expertise." Every engineer should know how to manage risks while making tradeoffs with cost, convenience, and other factors. Creating a functional or economical product or system is not enough. It also must be safe. Engineers cannot set arbitrary standards to determine when something is safe enough. They must be knowledgeable about the thousands of standards society has established. Engineers must work with society and other professions in meeting the health and safety challenge of registration laws: "To protect public health, safety and welfare."

## EXERCISES

1. Discuss who should set safety and health standards.
2. Discuss the public confidence in engineering and technology.
3. Discuss the effectiveness of registration laws in protecting public health and safety.
4. Find out what accreditation criteria exist to ensure that safety and health are incorporated into engineering and engineering technology education.
5. Contact the National Safety Council's Institute for Safety Through Design to find examples of designs which incorporate safety.

## REVIEW QUESTIONS

1. How many chemical substances are registered? Are in use?
2. How many accidental deaths occur each year in the United States? How are these distributed among work, vehicles, and home?
3. How many disabling injuries occur each year in the United States?
4. What is the annual cost of accidents in the United States?
5. What means has society used to reduce safety and health risks resulting from technological advances?
6. Are job-related illnesses well represented in accident and death statistics? Explain.
7. Approximately how many hazardous waste sites are known to exist in the United States?
8. What is the one common reason for state engineering registration laws?
9. What measures help ensure that engineers have some competency in dealing with health and safety in practice?

## NOTES

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CHAPTER 2

# SAFETY AND HEALTH PROFESSIONS

## 2-1 INTRODUCTION

Keeping people safe involves the work of many disciplines. Engineers have made many contributions to safety and have helped resolve many safety problems; so have many other professions. Engineers need to know what role other professions have in safety and health and need to work with them. Often an interdisciplinary effort is required to identify hazards, to develop effective solutions to safety problems, and to achieve safe products, buildings, operations, and systems.

In today's high-technology society, no individual can be an expert in every aspect of safety and health. It is impossible to keep up with all the new laws and regulations at the federal, state, and local level. There are many changes and interpretations of them. To know everything about safety, one would have to be an expert in law, engineering, technical equipment, manufacturing processes, behavioral sciences, management, health sciences, finance, insurance, and other fields. Current safety professionals can be specialists in a particular area of safety. They also can function as generalists who coordinate and facilitate the actions of other knowledgeable professionals in applying safety principles to particular problems.

Sometimes people with limited safety training become involved in safety activities. There are many different reasons:

They may have a good knowledge of plant operations, a valuable characteristic.

They may have had an accident themselves and become a safety proponent.

They may know fellow workers well and have a good rapport with them, also important.

They may be good leaders and effective communicators.

These characteristics may make them good workers and advocates for safety, but do not give them the safety knowledge and skills necessary to deal effectively with complex and technical safety and health problems today. Achieving safety now involves professionals, often from a variety of backgrounds.

## 2-2 SAFETY PROFESSIONALS

Many individuals who moved into safety and health jobs from other fields learned the principles of safety and health on the job. Some learned safety through continuing education programs after joining into the field. Many began a safety and health career after study in specialized programs. More and more people entering the discipline today have baccalaureate and advanced degrees in safety and health.

There are many different specialists in the safety and health field. Many are safety professionals. A safety professional is "an individual who, by virtue of his specialized knowledge and skill and/or educational accomplishments, has achieved professional status in the safety field."[1] Without contributions from these different specialties, many of which are discussed herein, the safety field would not be where it is today.

Today, job analysis studies for certifications[2] define the tasks, knowledge, and skills required for safety professionals. Safety students need a solid foundation in mathematics and sciences (physics, chemistry, human physiology, and human behavior) and in business and technology. They receive specialized training in principles and practices of safety, industrial hygiene, ergonomics, and fire protection. They also receive some training in environmental matters and hazardous materials management.

Persons working in safety and health careers express a high level of job satisfaction. A 1990[3] salary survey showed that 90% of respondents were somewhat to highly satisfied with their careers in safety. Those holding nationally accredited certifications, such as the Certified Safety Professional (CSP),[4] earn significantly more than those with no certification.[5]

## 2-3 ENGINEERING

Every engineering discipline has important contributions to make to safety and health within its areas of specialization. Jobs in virtually every engineering discipline include a significant number of safety-related tasks.[6] At the risk of slighting some disciplines, contributions of certain disciplines are noted below. Engineers work mainly on the preventive side of safety. In this role, engineers must identify hazards during design and must eliminate or reduce them. They also prevent unsafe behavior by designing products, workplaces, and environments so that unsafe behavior cannot or is not likely to occur. They also mitigate the effects of unsafe behavior through design so that the effects are controlled or of limited scope.

### Civil Engineering

Civil engineers have advanced many areas of safety and health. Civil engineers pursue structural integrity of buildings, bridges, and other constructed facilities. Civil engineers seek safe and sanitary handling, storage, treatment, and disposal of wastes. They study and develop controls for air and water pollution and contribute to transportation safety in design and construction of facilities for railroads, motor vehicles, ships, and aircraft.

### Industrial Engineering

Being concerned with industrial processes and operations, industrial engineers try to fit jobs to people and make work methods and work environments safe. Many industrial engineers receive some training in occupational safety and health, safety engineering, ergonomics, or human factors engineering.

## Mechanical Engineering

Mechanical engineers took the lead in establishing safety requirements for machines, boilers and pressure vessels, elevators, and other kinds of mechanized equipment and facilities. They started safety standards for some of these systems before 1900.

## Electrical Engineering

Electrical engineers have contributed to safety through design of electrical safety devices, electrical interlocks, ground fault circuit interrupters, more compact electrical circuits, and other items. Today, electronics engineers and computer engineers must include software safety analysis in their designs to prevent injuries to system users.

## Chemical Engineering

Through the design of less hazardous processes, chemical engineers have contributed to safety. They have applied system safety techniques to process design, have helped develop requirements for less hazardous chemicals, and have developed waste reclamation processes.

## Safety Engineering

Safety engineering is devoted to the application of scientific and engineering principles and methods to the elimination and control of hazards. Safety engineers need to know a great deal about many different engineering fields. They specialize in recognition and control of hazards, and they work closely with other engineering and nonengineering disciplines.

## Ergonomics and Human Factors Engineering

Ergonomics and human factors engineering are very similar. They specialize in the application of information from the biological and behavioral sciences to the design of systems and equipment. Their goal is to improve performance, safety, and satisfaction. They try to improve the fit between people and equipment, environments, systems, work-places or information. Specialists in this field try to improve performance and safety by reducing task errors and physical stresses involved in physical activity. Ergonomics has a strong emphasis on physiological and biomechanical aspects whereas human factors engineering emphasizes the behavioral and cognitive aspects of performance and safety.

## Fire Protection Engineering

Fire protection engineering is the field of engineering concerned with safeguarding life and property against loss from fire, explosion, and related hazards. Fire protection engineers are specialists in prevention, protection, detection and alarms, and fire control and extinguishment for structures, equipment, processes, and systems. They design egress routes to allow for safe exiting from fires.

## 2-4 MANAGEMENT SCIENCES

People in business and personnel management also contribute to the advancement of the safety and health field. In some companies, a safety and health program is part of the personnel, human resources, or labor relations branch of the organization. Sometimes safety and health programs are part of a risk management or loss control unit. Other areas of management, such as advertising, marketing, sales, and procurement, can contribute to safety, too. For a number of years the National Institute of Occupational Safety and Health operated Project Minerva, which had a goal of advancing safety within the management sciences. Some management theories, such as those of Juran and Demming (see Chapter 34), offer constructs that aid management in reducing hazards and concurrently in improving the organization's quality and bottom line.

### Risk Management

The field of risk management attempts to reduce all types of losses to an acceptable level at the lowest possible cost. Risk managers often administer accident prevention, risk assessment, and insurance programs. Part of risk management is transferring risk through insurance.

### Loss Control Specialists

A loss control specialist is a person responsible for the development of programs to prevent or minimize business losses other than speculative losses. Losses include personal injury, damage to property, fire, explosion, theft, pilferage, vandalism, industrial espionage, air and water pollution, employee illness, and product defects.[7] Loss control and risk management are related. The casualty and property insurance industry employs loss control specialists who provide loss control assistance to policy holders. A job analysis study identifies the minimum tasks, knowledge, and skills for loss control specialists.[8]

## 2-5 HEALTH SCIENCES

The health sciences play an important role in safety. In the industrial workplace, it is common practice in large companies to see the safety professionals and the medical professionals working closely together. Although the task of physicians and nurses is to treat those who are ill and injured, much of their attention in safety is on prevention. In recent times, new specialties have emerged in the health field, including industrial hygienists, health physicists, toxicologists, environmental health specialists, public health specialists, and others.

### Occupational Medicine and Nursing

Occupational medicine applies medical science to the prevention and treatment of occupational injuries, illnesses, and diseases. Because there are fewer specialists in this field than needed, a number of medical schools received federal grants beginning in the 1970s to train physicians in occupational medicine. Occupational nurses often fill the role of health specialists in a company or plant when an occupational physician is not available.

### Industrial Hygiene

Industrial hygiene is the science and art devoted to the recognition, evaluation, and control of those environmental factors or stresses arising in or from work situations that may cause illness or impaired health.

### Health Physics

Health physics is a branch of medical physics concerned with protecting humans and their environments from unwarranted radiation exposure. Health physicists engage in the study of radiation problems and methods to provide radiation protection as well as study the mechanisms of radiation damage. They also develop and implement methods necessary to evaluate radiation hazards and to provide and properly use radiation protective equipment.

## 2-6 BEHAVIORAL SCIENCES AND EDUCATION

Among the behavioral sciences, psychologists sometimes work in health and safety. Some psychologists work directly in safety and health programs, whereas others contribute through the fields of human factors, organizational behavior, industrial psychology, or personnel management. Some psychologists specialize in behavior modifications to reduce accidents. Education specialists often develop training programs and apply training methods for safety and health. More recently, some specialists have applied behavioral modification theories to safety practices. The literature for achieving safety now includes the term *behavior based safety*.

## 2-7 LEGAL PROFESSION

Legal issues have long been a part of the safety and health field. Even before worker compensation laws came into existence, lawyers helped resolve work-related injury and illness claims. During the nineteenth and twentieth centuries, lawyers helped frame laws and regulations to protect workers, consumers, and the public. They played an important role in seeking just compensation and protection and in preventing unjust claims. Some believe that the legal profession has inhibited American business through liability litigation. However, litigation often improves the safety of products and workplaces. There are continued attempts to limit liability through legislation.

## 2-8 OTHER PROFESSIONS

Undoubtedly, other professions and interdisciplinary specialties play important roles in advancing the safety and health field. Naming some runs the risk of overlooking others that have made significant contributions.

### Architecture

Architects have contributed to safety and health in a number of ways. They are often responsible for the structural integrity of buildings and work closely with civil and structural engineers to prevent collapse. Architects work with fire protection engineers in developing and implementing life safety codes and other fire protection standards. Architects also can affect safety when selecting flooring and designing stairs and railings that prevent falls or when designing buildings to minimize risks during maintenance work. Their designs can affect safety for workstations, buildings, and sites.

### Urban Planning

Urban planners have developed zoning ordinances to remove congestion from lots and streets, and they have participated in the development and implementation of building codes and environmental standards. Urban planners are an integral part of teams working to reduce air and water pollution, to provide community fire protection, to separate housing from noisy and hazardous activities, and to improve traffic flow.

## 2-9 CERTIFICATION, REGISTRATION, AND PROFESSIONALISM

All states have laws governing the registration or licensing of certain professionals, such as engineers, architects, lawyers, and physicians. The one justification found in each of these laws is protection of the safety, health, and welfare of the public. Many disciplines that contribute to safety and health are not licensed.

Safety engineering is recognized as an engineering specialty in very few states. Most engineers who specialize in safety become registered as engineers in a traditional engineering field. In some states, there is no distinction among engineering specialties for reasons of registration. Licenced engineers are simply registered professional engineers.

In most engineering registration examinations, very few questions deal with safety and health. As a result, engineering registration does not ensure that an individual can recognize and control hazards. The engineering registration process and examinations often are criticized because of this. In fact, some believe that the public is not adequately protected through engineering registration.

For many disciplines not covered by registration laws, including some in safety and health, it is difficult to tell whether individuals really have professional qualifications. For disciplines that do not have state licensing, it is becoming commonplace to establish certification programs. A respected panel of professionals in the field usually oversees the program. Typically, candidates for certification must meet education and experience standards and must pass one or more professional practice examination. The process for certification is very similar to that for government-operated registration, but is managed by professional peer groups.

Certified Safety Professional (CSP), Certified Industrial Hygienist (CIH), and Certified Health Physicist (CHP) programs began in the 1960s. These programs follow strict education, experience, and examination procedures in awarding such designations to applicants. Boards of directors who are recognized for their professional qualifications in these fields manage these programs. These certifications are the most notable in safety and health. Today, peer certifications use accreditation to assure the public, employers, and government organizations that the programs adhere to quality procedures. The National Commission for Certifying Agencies (NCCA),[9] the Council of Engineering and Scientific Specialty Boards (CESB),[10] and the American National Standards Institute[11] publish standards for peer certification boards and operate accreditation programs for peer certification programs.

Individuals with certification do not have the same status under state laws that registered or licensed professionals do. The certification process provides an orderly means to assure the public and others that specialists have achieved certain professional standards. Over time employers, government units, the public, and the profession rely on peer certification to assess minimum competency in particular disciplines. One frequently finds government agencies and companies requiring certification for certain positions or job functions in contracts and when recruiting.

In the future engineers will probably be required to demonstrate competence in safety and health more than they do now. Safety and health will probably receive greater attention in engineering courses and degree programs. Accreditation reviews for engineering programs will look for safety and health training. Engineering registration examinations undoubtedly will contain more questions dealing with particular safety and health issues. In the future, engineering registration and certification may involve a two-tier process: registration in engineering by states, followed by peer group certification in specialties.

## EXERCISES

1. Develop a library of course catalogs and brochures for academic programs in safety and health. Visit the database of safety and related academic programs on the web site of the Board of Certified Safety Professionals: www.bcsp.org.
2. Talk to active safety and health professionals. Report on such things as how they entered their field, where they received their training, what their responsibilities are, what job challenges they have experienced, and how they achieve job satisfaction.

## REVIEW QUESTIONS

1. Explain why safety and health specialists must work as a team, both within the safety and health field and with others professions outside the field.
2. Define the main responsibilities of the following specialties:
   (a) safety engineer
   (b) human factors engineer
   (c) fire protection engineer
   (d) risk manager
   (e) physician in occupational medicine
   (f) industrial hygienist
   (g) health physicist
3. Explain the major differences between registration and certification.
4. Explain how quality of peer certification programs can be verified.
5. What peer certifications are highly recognized in the safety and health field?
6. What is the one reason used to justify state laws that establish registration for engineers?

## NOTES

**1** *The Dictionary of Terms Used in the Safety Profession*, 3rd ed., American Society of Safety Engineers, Des Plaines, IL, 1988.

**2** "Job Analysis Study for Certified Safety Professional Examinations," BCSP Technical Report 2001-1, Board of Certified Safety Professionals, Savoy, IL, February 2001.

**3** *Member Salary Survey,* American Society of Safety Engineers, Des Plaines, IL, 1990.

**4** Certified Safety Professional and CSP are certification marks issued by the U.S. Patent and Trademark Office to the Board of Certified Safety Professionals.

**5** "Professional Certification: Its Value to SH&E Practitioners and the Profession," *Professional Safety*, 49:12:26–31 (2004).

**6** *A Task Analysis of Licensed Engineers*, National Council of Engineering Examiners, Clemson, SC, updated periodically.

**7** J. A. Fletcher, *The Industrial Environment—Total Loss Control*, National Profile Limited, Willowdale, Ontario, Canada, 1972.

**8** *Role Delineation Study for Occupational Health and Safety Technologist and Loss Control Specialist Examinations*, CCHEST Technical Report 2003-1, Council on Certification of Health, Environmental and Safety Technologists, March 2003.

**9** National Commission for Certifying Agencies, 1200 19th Street, NW, Suite 300, Washington, DC

**10** Council of Engineering and Scientific Specialty Boards, 130 Holiday Court, Suite 100, Annapolis, MD 21401.

**11** American National Standards Institute, 1819 L Street NW, 6th Floor, Washington, DC 20036, operates ISO/IEC 17024 (Certification of Persons) within the United States.

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