

# 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*.<sup>1</sup> 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.

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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.<sup>2</sup>

## 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 accidentally 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.<sup>3</sup>

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,<sup>4</sup> 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,<sup>5</sup> 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.

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## **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.<sup>6</sup>

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<sup>7</sup> 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

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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,<sup>8</sup> 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.<sup>9</sup>

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 Amendment.

### 1-4 TRANSPORTATION

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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 rammmed the Sunshine Skyway Bridge in St. Petersburg, Florida, ripping out a 1,400-ft section. Thirty-one people died as their vehicles plunged 140ft 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**

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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**

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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.<sup>10</sup>

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."<sup>11</sup>

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.<sup>12</sup> 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.<sup>13</sup>

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.<sup>14</sup> 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 stan-

dards 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

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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

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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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**12** *National Congress on Engineering Education*, Accreditation Board for Engineering and Technology, New York, November 1986.

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