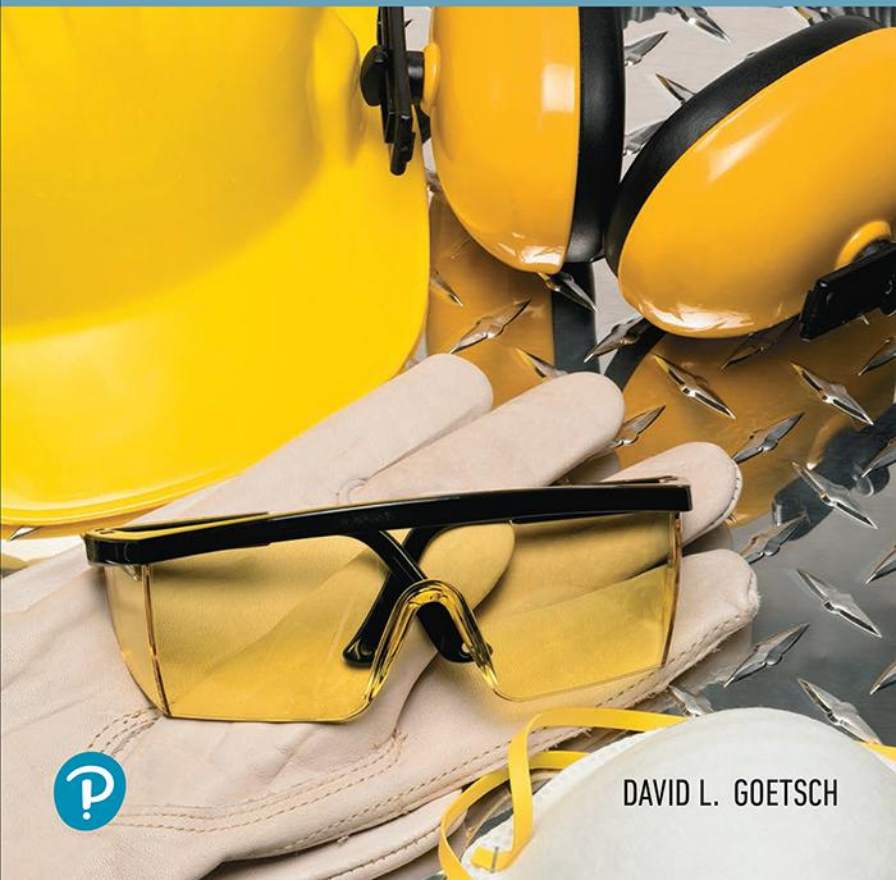
THIRD EDITION

THE BASICS OF OCCUPATIONAL SAFETY



DAVID L. GOETSCH

Third Edition

THE BASICS OF OCCUPATIONAL SAFETY

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Preface

BACKGROUND

The field of occupational safety and health has undergone significant change over the past three decades. There are many reasons for this. Some of the more prominent reasons include technological changes that have introduced new hazards in the workplace; proliferation of health and safety legislation and corresponding regulations; increased pressure from regulatory agencies; realization by executives that workers in a safe and healthy workplace are typically more productive; healthcare and workers' compensation cost increases; increased pressure from environmental groups and the public; a growing interest in ethics and corporate social responsibility; professionalization of health and safety occupations; increased pressure from labor organizations and employees in general; rapidly mounting costs associated with product safety and other types of litigation; and increasing incidents of workplace violence.

All of these factors, when combined, have made the job of the modern safety and health professional more challenging and more important than it has ever been. These factors have also created a need for an up-to-date book on the basics of workplace safety and health that contains the latest information needed by people who will have responsible positions in today's fast-paced, competitive workplace.

WHY IS THIS BOOK WRITTEN AND FOR WHOM?

This book is written to fulfill the need for an up-to-date, practical teaching resource that focuses on the basic safety-related needs of people in the workplace. It is intended for use in universities, colleges, community colleges, technical schools, and corporate training settings that offer programs, courses, workshops, and seminars in occupational safety and health. Educators and students in such disciplines as safety engineering, engineering, industrial technology, manufacturing technology, industrial engineering, safety engineering, engineering technology, occupational safety, management, and supervision will find this book both valuable and easy to use. The direct, straightforward presentation of material focuses on making the theories and principles of occupational safety and health practical and useful in a real-world setting. Up-to-date research has been integrated throughout in a down-to-earth manner.

ORGANIZATION OF THE BOOK

The text contains 20 chapters, each focusing on a major area of concern in workplace safety and health. The chapters are presented in an order that is compatible with the typical organization of a college-level safety and health course. A standard chapter

format is used throughout the book. There is a list of learning objectives at the beginning of each chapter. All chapters include review questions, key terms and concepts, and endnotes. These materials are provided to encourage review, stimulate additional thought, and provide opportunities for applying what has been learned.

INSTRUCTOR RESOURCES

To access supplementary materials online, instructors need to request an instructor access code. Go to **www.pearsonhighered.com/irc** to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement and a login page will appear. Once you have logged in, you can access instructor material for all Pearson textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at **http://support.pearson.com/getsupport**.

HOW THIS BOOK DIFFERS FROM OTHERS

This book is written because, in the age of global competition, safety and health in the workplace have changed drastically. Many issues, concerns, and factors relating specifically to modern workplace environments have been given more attention, greater depth of coverage, and more illumination here than in other textbooks. Some of the areas receiving more attention and specific occupational examples include the following:

- The Occupational Safety and Health Act (OSH Act) and Occupational Safety and Health Administration (OSHA)
- Standards and codes
- Laws and liability
- Stress-related problems
- Fire hazards and life safety
- The evolving roles of health and safety professionals
- Health and safety training
- Human factors in safety
- Bloodborne pathogens in the workplace
- Ergonomics and safety
- Workers' compensation
- Repetitive strain injuries (RSIs)

NEW TO THIS EDITION

The third edition of *The Basics of Occupational Safety* is a major revision encompassing new regulations, revised regulations, and other new and updated material of importance for the students of occupational safety and health. Specifically, the following revisions are made in the third edition:

CHAPTER 1:

1. Added a section about safety applying to all work sectors: manufacturing, retail, hospitality, healthcare, etc.
2. Added information on the Chemical Safety Board.
3. Added information on ergonomics as a trend in safety in the 1990s.
4. Added information on the West Fertilizer Company tragedy.
5. Added information on whether the accident rate has decreased because America has lost so many manufacturing jobs.

CHAPTER 2:

1. Moved "Heat Burns and Chemical Burns" sections to Chapter 15.
2. Moved "Repetitive Strain/Soft Tissue Injuries" section to Chapter 8.
3. Added a reference year to Figures 2–1, 2–2, and 2–3 so students know when the data was compiled.
4. Added a brief section on OSHA reports and logs here (and reference where they appear in detail in Chapter 5).
5. Converted Figure 2–4 into a chart.
6. Added a link to Bureau of Labor Statistics for more detailed information.

CHAPTER 3:

1. Bolded the sentence about Heinrich's Theory being discounted by contemporary research for emphasis.
2. Added information on James Reason's Swiss Cheese Model of accident causation.
3. Changed the section on "Drugs and Accident Causation" to "Individual Factors and Accident Causation" (includes drugs, depression, obesity, fatigue, personality, etc.).

CHAPTER 4:

1. Added information on the importance of the employee on safety teams and the employee's role in safety.
2. Replaced Figures 4–9 and 4–10 with photographs.

CHAPTER 5:

1. Added information on indirect costs of OSHA fines (bad PR, loss of goodwill, corporate image, legal fees, paperwork, etc.).
2. Replaced Figure 5–4 with instructions for finding consultation services in your state.
3. Revised Figure 5–5 to include website addresses for each agency instead of street addresses.
4. Updated the OSHA standard subparts listed to ensure they are up to date.
5. Added information on where the fines go when OSHA collects them and discussion plus examples about the size of fines.

CHAPTER 6:

1. Replaced Figure 6–1 with a figure showing how students can access workers' compensation information for their states.
2. Added information on workers' compensation abuse (employees trying to take advantage of the system).
3. Replaced Figure 6–2 with a photograph.

CHAPTER 7:

1. Added information about why safety professionals who do accident reports need to be familiar with common causes of accidents (added to the "Common Causes of Accidents" section).
2. Added a section on "Who is responsible for reporting."
3. Added an accident investigation exercise to the end of the chapter.

CHAPTER 8:

1. Added information on ergonomic assessment tools such as NIOSH guidelines, RULA, and REBA.
2. Moved section on "lifting" from Chapter 11 to this chapter and expanded the content of the section.
3. Expanded the section on "Human Factors and Safety."
4. Added information on choosing which workstations/operations to evaluate for ergonomics to the section on "Worksite Analysis Program."
5. In the section titled "Training and Education," referred students to using recommended training materials from OSHA.
6. In the section on "Identifying Specific Ergonomic Problems" added material on "anthropometry" (body size).
7. In the section on "Helpful Assessment Tools: NIOSH, RULA, REBA, and HAL" (added information on analysis tools including RULA, REBA, HAL, and Strain Index).

CHAPTER 9:

1. Explained how the list of "common causes" can be used and how it relates to the rest of the chapter.
2. Added explanations for the strategies for dealing with stress.
3. Added physiological measures of stress (heart rate, pupil dilation, perspiration, etc.).
4. Added information about 24/7 use of technology and multitasking as causes of stress.
5. Added information about Employee Assistance Programs (EAPs) and company wellness programs for dealing with stress.

CHAPTER 10:

1. Added information about how a given type of machine guard is chosen.
2. Added information on advanced sensors and Bluetooth technology.

CHAPTER 11:

1. Dropped "Lifting" from the title to this chapter, and moved the section on lifting to Chapter 8.
2. Changed title to "Falling, Impact, Acceleration, and Vision Hazards with Appropriate PPE."

CHAPTER 12:

1. Added information on Clo as a unit for measure for PPE temperature protection.
2. Added a section on OSHA recommendations and guidelines for temperature hazards.
3. Added a note to "Chemical Burns" explaining why it is in this chapter and not in the chapter on fire safety.

CHAPTER 13:

1. Added a note that refers students to Chapter 16 for coverage of "Confined Spaces."
2. Added information on 29 CFR 1910 Subpart H (OSHA's standards on pressure hazards).

CHAPTER 14:

1. Added information about power strips and daisy chains.
2. Made minor updates corrections to the text.

CHAPTER 15:

1. Added information about the number of fire extinguishers needed, how to choose the type, and where they should be located in a facility.
2. Moved sections on "Chemical Burns" from Chapter 2 to this chapter.
3. Added information to the "egress" section about lighting and signage.
4. Strengthened the material on "egress."

CHAPTER 16:

1. Added information to describe TWA in more detail.
2. Removed the underline from the TWA side of the equation.

CHAPTER 17:

1. Expanded the explanations of risk reduction strategies.

CHAPTER 18:

1. Added a section about "earbuds" from handheld devices and potential hazards.
2. In the section on "Hazard Levels and Risks" added information from Chapter 16 on calculating TWA.
3. In the section on "Vibration Hazards" added information about tools insulation, tool mounting, and job rotation.

4. In the section on "Noise Control Strategies" added information on specific engineering controls (e.g., mufflers, insulation, wall panels, and sound absorption).
5. Added information about calculating Noise Reduction Rating (NRR) and how to evaluate PPE based on the NRR.
6. Moved the section on "Fit Testing" to earlier in the chapter.

CHAPTER 19:

1. Added a section on "active shooter" response.
2. Added a section on "reporting suspicious activities."

ABOUT THE AUTHOR

David L. Goetsch is vice president Emeritus of Northwest Florida State College and professor of safety, quality, and management. In addition, Dr. Goetsch is president and CEO of the Institute for Organizational Excellence (IOE), a private consulting firm dedicated to the continual improvement of organizational competitiveness, safety, and quality. Dr. Goetsch is cofounder of The Quality Institute, a partnership of the University of West Florida, Northwest Florida State College, and the Okaloosa Economic Development Council and founder of the Leadership Institute of Northwest Florida State College and founder of the Leadership Institute of Northwest Florida State College.

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Introduction

SAFETY VERSUS HEALTH

Throughout the text, the titles "safety and health professional" and "safety and health manager" are used. This, too, is done by design. This approach underscores the point that the field of occupational safety has been broadened to encompass both safety and health. Consequently, managers, technical personnel, and engineers in this field must be knowledgeable about safety and health and be prepared to oversee a program that encompasses both areas of responsibility.

Safety and health, although closely related, are not the same. One view is that safety is concerned with injury-causing situations, whereas health is concerned with disease-causing conditions. Another view is that safety is concerned with hazards to humans that result from sudden severe conditions; health deals with adverse reactions to prolonged exposure to dangerous, but less intense, hazards. Both of these views are generally accurate in portraying the difference between safety and health. However, the line between these two concepts is not always clearly marked.

For example, stress is a hazard that can cause both psychological and physiological problems over a prolonged period. In this case, it is a health concern. On the other hand, an overly stressed worker may be more prone to unintentionally overlook safety precautions and thus may cause an accident. In this case, stress is a safety concern.

Because personnel in this evolving profession are likely to be responsible for safety *and* health, it is important that they have a broad academic background covering both. This book attempts to provide that background.

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Brief Contents

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Contents

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CHAPTER

1 SAFETY AND HEALTH MOVEMENT, THEN AND NOW

Learning Objectives

- Summarize key developments relating to workplace safety and health prior to the Industrial Revolution
- List the most important milestones in the safety movement
- Explain how workplace tragedies have changed the safety movement
- Describe the role of organized labor in the safety movement
- Describe the roles specific health problems have played in the safety movement
- Explain how safety and health standards apply to more than just manufacturing
- Describe the development of accident prevention programs as part of the safety movement
- Describe the safety and health movement today
- Explain the integrated approach to safety and health
- Describe how new materials, new processes, and new problems are affecting the safety and health movement today
- Summarize the rapid growth that has occurred in the safety and health profession
- Explain how the movement of manufacturing jobs overseas has affected the accident rate in the United States

The **safety movement** in the United States has developed steadily since the early 1900s. In that time period, industrial accidents were commonplace in this country; for example, in 1907, more than 3,200 people were killed in mining accidents. Legislation, precedent, and public opinion all favored management. There were few protections for workers' safety.

Working conditions for industrial employees today have improved significantly. The chance of a worker being killed in an industrial accident is less than half of what it was 60 years ago.[1] According to the National Safety Council (NSC), the current death rate from work-related injuries is approximately 4 per 100,000, or less than a third of the rate 50 years ago.[2]

Improvements in safety until now have been the result of pressure for legislation to promote safety and health, the steadily increasing costs associated with accidents and injuries, and the professionalization of safety as an occupation. Improvements in the future are likely to come as a result of greater awareness of the cost-effectiveness and resultant competitiveness gained from a safe and healthy workforce.

This chapter examines the history of the safety movement in the United States and how it has developed over the years. Such a perspective will help practicing and prospective safety professionals form a better understanding of both their roots and their future.

DEVELOPMENTS BEFORE THE INDUSTRIAL REVOLUTION

It is important for students of occupational health and safety to first study the past. Understanding the past can help safety and health professionals examine the present and future with a sense of perspective and continuity. Modern developments in health and safety are neither isolated nor independent. Rather, they are part of the long continuum of developments in the safety and health movement.

The continuum begins with the days of the ancient Babylonians. During that time, circa 2000 BC, their ruler, Hammurabi, developed his **Code of Hammurabi**. The code encompassed all the laws of the land at that time, showed Hammurabi to be a just ruler, and set a precedent followed by other Mesopotamian kings. The significance of the code from the perspective of safety and health is that it contained clauses dealing with injuries, allowable fees for physicians, and monetary damages assessed against those who injured others.[3] This clause from the code illustrates Hammurabi's concern for the proper handling of injuries: "If a man has caused the loss of a gentleman's eye, his own eye shall be caused to be lost."[4]

This movement continued and emerged in later Egyptian civilization. As evidenced from the temples and pyramids that still remain, the Egyptians were an industrious people. Much of the labor was provided by slaves, and there is ample evidence that slaves were not treated well—that is, unless it suited the needs of the Egyptian taskmasters.

One such case occurred during the reign of Rameses II (circa 1500 BC), who undertook a major construction project, the Ramesseum. To ensure the maintenance of a workforce sufficient to build this huge temple bearing his name, Rameses created an industrial medical service to care for the workers. They were required to bathe daily in the Nile and were given regular medical examinations. Sick workers were isolated.[5]

The Romans were vitally concerned with safety and health, as can be seen from the remains of their construction projects. The Romans built aqueducts, sewerage systems, public baths, latrines, and well-ventilated houses.[6]

As civilization progressed, so did safety and health developments. In 1567, Philippus Aureolus produced a treatise on the pulmonary diseases of miners. Titled

On the Miners' Sickness and Other Miners' Diseases, the treatise covered diseases of smelter workers and metallurgists and diseases associated with the handling of and exposure to mercury. Around the same time, Georgius Agricola published his treatise *De Re Metallica*, emphasizing the need for ventilation in mines and illustrating various devices that could be used to introduce fresh air into mines.[7]

The eighteenth century saw the contributions of Bernardino Ramazzini, who wrote *Discourse on the Diseases of Workers*. Ramazzini drew conclusive parallels between diseases suffered by workers and their occupations. He related occupational diseases to the handling of harmful materials and to irregular or unnatural movements of the body. Much of what Ramazzini wrote is still relevant today.[8]

The Industrial Revolution changed forever the methods of producing goods. According to J. LaDou, the changes in production brought about by the Industrial Revolution can be summarized as follows:

- Introduction of **inanimate power** (i.e., steam power) to replace people and animal power
- Substitution of machines for people
- Introduction of new methods for converting raw materials
- Organization and specialization of work, resulting in a division of labor[9]

These changes necessitated a greater focusing of attention on the safety and health of workers. Steam power increased markedly the potential for life-threatening injuries, as did machines. The new methods used for converting raw materials also introduced new risks of injuries and diseases. Specialization, by increasing the likelihood of boredom and inattentiveness, also made the workplace a more dangerous environment.

MILESTONES IN THE SAFETY MOVEMENT

Just as the United States traces its roots to Great Britain, the safety movement in this country traces its roots to England. During the Industrial Revolution, child labor in factories was common. The hours were long, the work hard, and the conditions often unhealthy and unsafe. Following an outbreak of fever among the children working in their cotton mills, the people of Manchester, England, began demanding better working conditions in the factories. Public pressure eventually forced a government response, and in 1802 the Health and Morals of Apprentices Act was passed. This was a milestone piece of legislation: It marked the beginning of governmental involvement in workplace safety.

When the industrial sector began to grow in the United States, hazardous working conditions were commonplace. Following the Civil War, the seeds of the safety movement were sown in this country. Factory inspection was introduced in Massachusetts in 1867. In 1868, the first barrier safeguard was patented. In 1869, the Pennsylvania legislature passed a mine safety law requiring two exits from all mines. The Bureau of Labor Statistics (BLS) was established in 1869 to study industrial accidents and report pertinent information about those accidents.

The following decade saw little new progress in the safety movement until 1877, when the Massachusetts legislature passed a law requiring safeguards for hazardous machinery. This year also saw passage of the Employer's Liability Law, establishing

the potential for **employer liability** in workplace accidents. In 1892, the first recorded safety program was established in a Joliet, Illinois, steel plant in response to a scare caused when a flywheel exploded. Following the explosion, a committee of managers was formed to investigate and make recommendations. The committee's recommendations were used as the basis for the development of a safety program that is considered to be the first safety program in American industry.

Around 1900, Frederick Taylor began studying efficiency in manufacturing. His purpose was to identify the impact of various factors on efficiency, productivity, and profitability. Although safety was not a major focus of his work, Taylor did draw a connection between lost personnel time and management policies and procedures. This connection between safety and management represented a major step toward broad-based safety consciousness.

In 1907, the U.S. Department of the Interior created the Bureau of Mines to investigate accidents, examine health hazards, and make recommendations for improvements. Mining workers definitely welcomed this development, since more than 3,200 of their fellow workers were killed in mining accidents in 1907 alone.[10]

One of the most important developments in the history of the safety movement occurred in 1908 when an early form of **workers' compensation** was introduced in the United States. Workers' compensation actually had its beginnings in Germany. The practice soon spread throughout the rest of Europe. Workers' compensation as a concept made great strides in the United States when Wisconsin passed the first effective workers' compensation law in 1911. In the same year, New Jersey passed a workers' compensation law that withstood a court challenge.

The common thread among the various early approaches to workers' compensation was that they all provided some amount of compensation for on-the-job injuries regardless of who was at fault. When the workers' compensation concept was first introduced in the United States, it covered a very limited portion of the workforce and provided only minimal benefits. Today, all 50 states have some form of workers' compensation that requires the payment of a wide range of benefits to a broad base of workers. Workers' compensation is examined in more depth in Chapter 6.

The Association of Iron and Steel Electrical Engineers (AISEE), formed in the early 1900s, pressed for a national conference on safety. As a result of the AISEE's efforts, the first meeting of the **Cooperative Safety Congress (CSC)** took place in Milwaukee in 1912. What is particularly significant about this meeting is that it planted the seeds for the eventual establishment of the NSC. A year after the initial meeting of the CSC, the **National Council of Industrial Safety (NCIS)** was established in Chicago. In 1915, this organization changed its name to the National Safety Council. It is now the premier safety organization in the United States.

From the end of World War I (1918) through the 1950s, safety awareness grew steadily. During this period, the federal government encouraged contractors to implement and maintain a safe work environment. Also during this period, industry in the United States arrived at two critical conclusions: (1) there is a definite connection between quality and safety, and (2) off-the-job accidents have a negative impact on productivity. The second conclusion became painfully clear to manufacturers during World War II when the call-up and deployment of troops had employers struggling to meet their labor needs. For these employers, the loss of a skilled worker due to an injury or for any other reason created an excessive hardship.[11]

The 1960s saw the passage of a flurry of legislation promoting workplace safety. The Service Contract Act of 1965, the Federal Metal and Nonmetallic Mine Safety Act, the Federal Coal Mine and Safety Act, and the Contract Workers and Safety Standards Act all were passed during the 1960s. As their names indicate, these laws applied to a limited audience of workers.

These were the primary reasons behind passage of the **Occupational Safety and Health Act (OSH Act)** of 1970 and the Federal Mine Safety Act of 1977. These federal laws, particularly the OSH Act, represent the most significant legislation to date in the history of the safety movement. During the 1990s, the concept of Total Safety Management (TSM) was introduced and adopted by firms that were already practicing Total Quality Management (TQM). TSM encourages organizations to take a holistic approach to safety management in which the safety of employees, processes, and products is considered when establishing safe and healthy work practices.

At the turn of the century, workplace violence, including terrorism, began to concern safety and health professionals. In addition, the twenty-first century saw a trend in which older people were returning to work to supplement their retirement income. This trend led to a special emphasis on the safety and health of older workers. A more recent trend is greater concern of U.S. companies for the safety and health of employees in foreign countries that manufacture goods that are sold in the United States.

The Superfund Amendments and Reauthorization Act was passed by Congress in 1986, followed by the Amended Clean Air Act in 1990; both were major pieces of environmental legislation. Another milestone that occurred in the decade of the 1990s was the trend toward safety professionals making ergonomics part of their overall approach for preventing accidents and injuries. Ergonomics involves fitting the work to the worker rather than the worker to the work. It is concerned with, among other things, the prevention of musculoskeletal disorders (MSDs) and injuries.

Figure 1–1 summarizes some significant milestones in the development of the safety movement in the United States.

TRAGEDIES THAT HAVE CHANGED THE SAFETY MOVEMENT

The pace of the safety and health movement in the United States has been accelerated by the occurrence of workplace tragedies. These tragedies could have been prevented had appropriate safety and health measures been followed. Unfortunately, they were not. This section summarizes some of the more significant of these workplace tragedies; tragedies that have had a lasting effect on the safety and health movement.

Hawk's Nest Tragedy

In the 1930s, the public began to take notice of the health problems suffered by employees who worked in dusty environments. The Great Depression was indirectly responsible for the attention given to an occupational disease that came to be known as *silicosis*. As the economic crash spread, business after business shut down and laid off its workers. Unemployed miners and foundry workers began to experience problems finding new jobs when physical examinations revealed that they had lung damage from breathing silica. Cautious insurance companies recommended preemployment physicals as a way

FIGURE 1–1 Milestones in the safety movement.

1867	Massachusetts introduces factory inspection.
1868	Patent is awarded for first barrier safeguard.
1869	Pennsylvania passes law requiring two exits from all mines, and the Bureau of Labor Statistics is formed.
1877	Massachusetts passes law requiring safeguards on hazardous machines, and the Employer's Liability Law is passed.
1892	First recorded safety program is established.
1900	Frederick Taylor conducts first systematic studies of efficiency in manufacturing. Followed by the motion studies of Frank Gilbreth.
1907	Bureau of Mines is created by U.S. Department of the Interior.
1908	Concept of workers' compensation is introduced in the United States.
1911	Wisconsin passes the first effective workers' compensation law in the United States, and New Jersey becomes the first state to uphold a workers' compensation law.
1912	First Cooperative Safety Congress meets in Milwaukee.
1913	National Council of Industrial Safety is formed.
1915	National Council of Industrial Safety changes its name to National Safety Council.
1916	Concept of negligent manufacture is established (product liability).
1924	Hawthorne Light Experiments.
1936	National Silicosis Conference convened by the U.S. Secretary of Labor.
1970	Occupational Safety and Health Act passes.
1977	Federal Mine Safety Act passes.
1978	OSHA offers education and training grants.
1980	OSHA coverage extended to federal employees.
1986	Superfund Amendments and Reauthorization Act pass.
1990	Amended Clean Air Act of 1970 passes. Also, safety professionals begin to apply the principles of ergonomics.
1996	Total safety management (TSM) concept is introduced.
2000	U.S. firms begin to pursue ISO 14000 registration for environmental safety management.
2003	Workplace violence and terrorism are an ongoing concern of safety and health professionals.
2007	Safety of older people reentering the workplace becomes an issue.
2009	Global Harmonization System for chemicals established.
2010	Off-the-job safety becomes an issue.
2017	Pressure on foreign companies that produce goods sold in the United States to improve their safety standards.

to prevent future claims based on preexisting conditions. Applicants with silica-damaged lungs were refused employment. Many of them sued. This marked the beginning of industry-wide interest in what would eventually be called the "king" of occupational diseases.

Lawsuits and insurance claims generated public interest in silicosis, but it was the Hawk's Nest tragedy that solidified public opinion in favor of protecting workers from this debilitating disease.[12] A company was given a contract to drill a passageway through a mountain located in the Hawk's Nest region of West Virginia (near the city of Gauley Bridge). Workers spent as many as 10 hours per day breathing the dust created by drilling and blasting. It turned out that this particular mountain had an unusually high silica content. Silicosis is a disease that normally takes 10–30 years to show up in exposed workers. At Hawk's Nest, workers began dying in as little time as a year. By the time the project was completed, hundreds had died. To make matters even worse, the company often buried an employee who died from exposure to silica in a nearby field without notifying the family. Those who inquired were told that their loved one left without saying where he was going.

A fictitious account of the Gauley Bridge disaster titled *Hawk's Nest*, by Hubert Skidmore, whipped the public outcry into a frenzy, forcing Congress to respond.

This tragedy and the public outcry that resulted from it led a group of companies to form the Air Hygiene Foundation to conduct research and develop standards for working in dusty environments. Soon thereafter, the U.S. Department of Labor provided the leadership necessary to make silicosis a compensable disease under workers' compensation in most states. Today, dust-producing industries use a wide variety of administrative controls, engineering controls, and personal protective equipment to protect workers in dusty environments. However, silicosis is still a problem. Approximately 1 million workers in the United States are still exposed to silica every year, and 250 people die annually from silicosis.

Asbestos Menace

Asbestos was once considered a "miracle" fiber, but in 1964, Dr. Irving J. Selikoff told 400 scientists at a conference on the biological effects of asbestos that this widely used material was killing workers. This conference changed how Americans viewed not just asbestos but also workplace hazards in general. Selikoff was the first to link asbestos to lung cancer and respiratory diseases.[13]

At the time of Selikoff's findings, asbestos was one of the most widely used materials in the United States. It was found in homes, schools, offices, factories, ships, and even in the filters of cigarettes. Selikoff continued to study the effects of asbestos exposure from 1967 to 1986. During this time, he studied the mortality rate of 17,800 workers who had been exposed to asbestos. He found asbestos-related cancer in the lungs, gastrointestinal tract, larynx, pharynx, kidneys, pancreas, gall bladder, and bile ducts of workers.

Finally, in the 1970s and 1980s, asbestos became a controlled material. Regulations governing the use of asbestos were developed, and standards for exposure were established. Asbestos-related lawsuits eventually changed how industry dealt with this tragic material. In the 1960s, industry covered up or denied the truth about asbestos. Now, there is an industry-wide effort to protect workers who must remove asbestos from old buildings and ships during remodeling, renovation, or demolition projects.

Bhopal Tragedy

On the morning of December 3, 1984, over 40 tons of methyl isocyanate (MIC) and other lethal gases, including hydrogen cyanide, leaked into the northern end of Bhopal, killing more than 3,000 people in its aftermath.[14] After the accident, it was discovered that the protective equipment that could have halted the impending disaster was not in full working order. The refrigeration system that should have cooled the storage tank was shut down, the scrubbing system that should have absorbed the vapor was not immediately available, and the flare system that would have burned any vapor that got past the scrubbing system was out of order.[15]

The International Medical Commission visited Bhopal to assess the situation and found that as many as 50,000 other people had been exposed to the poisonous gas and may still suffer disability as a result. This disaster shocked the world. Union Carbide Corporation, the owner of the chemical plant in Bhopal, India, where the incident occurred, was accused of many things, including the following:

- **Criminal negligence.**
- **Corporate prejudice.** Choosing poverty-stricken Bhopal, India, as the location for a hazardous chemical plant on the assumption that few would care if something went wrong.
- **Avoidance.** Putting its chemical plant in Bhopal, India, to avoid the stricter safety and health standards of the United States and the Occupational Safety and Health Administration (OSHA) in particular.

In February 1989, India's Supreme Court ordered Union Carbide India Ltd. to pay $470 million in compensatory damages. The funds were paid to the Indian government to be used to compensate the victims. This disaster provided the impetus for the passage of stricter safety legislation worldwide. In the United States, it led to the passage of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986.

Factory Fire in Bangladesh

In November 2012, a garment-factory fire in Bangladesh killed 112 employees. The magnitude of the tragedy was enhanced when it was discovered that the factory produced garments to sell in several major retail outlets in the United States. Fire inspectors suspect that an electrical short circuit caused the blaze, which spread quickly because of the flammable nature of material used to produce T-shirts in the factory. There were complaints that well-known retailers in the United States, and elsewhere in the Western world, were partially culpable in the tragedy because there was evidence that they knew of the unsafe conditions beforehand.

The garment factory in question had a functioning fire alarm and the alarm did go off properly. Unfortunately, supervisors demanded that workers go back to their sewing machines and even blocked an exit door workers could have used to escape the conflagration. It was learned in the subsequent investigation that the factory's fire extinguishers did not work and were displayed only to fool inspectors. A follow-up investigation revealed that 100 workers had been burned to death inside the factory while another 12 jumped to their deaths to escape the flames. This tragedy added to the mounting pressure for U.S. companies that contract with offshore manufacturers to pressure those manufacturers to implement safe and healthy work practices.

ROLE OF ORGANIZED LABOR

Organized labor has played a crucial role in the development of the safety movement in the United States. From the outset of the Industrial Revolution in this country, organized labor has fought for safer working conditions and appropriate compensation for workers injured on the job. Many of the earliest developments in the safety movement were the result of long and hard-fought battles by organized labor.

Although the role of unions in promoting safety is generally acknowledged, one school of thought takes the opposite view. Proponents of this dissenting view hold that union involvement actually slowed the development of the safety movement. Their theory is that unions allowed their demands for safer working conditions to become entangled with their demands for better wages; as a result, they met with resistance from management. Regardless of the point of view, there is no question that working conditions in the earliest years of the safety movement were often reflective of an insensitivity to safety concerns on the part of management.

Among the most important contributions of organized labor to the safety movement was their work to overturn antilabor laws relating to safety in the workplace. These laws were the fellow servant rule, the statutes defining contributory negligence, and the concept of assumption of risk.[16] The **fellow servant rule** held that employers were not liable for workplace injuries that resulted from the negligence of other employees. For example, if Worker X slipped and fell, breaking his back in the process, because Worker Y spilled oil on the floor and left it there, the employer's liability was removed. In addition, if the actions of employees contributed to their own injuries, the employer was absolved of any liability. This was the doctrine of **contributory negligence**. The concept of **assumption of risk** was based on the theory that people who accept a job assume the risks that go with it. It says employees who work voluntarily should accept the consequences of their actions on the job rather than blame the employer.

Because the overwhelming majority of industrial accidents involve negligence on the part of one or more workers, employers had little to worry about. Therefore, they had little incentive to promote a safe work environment. Organized labor played a crucial role in bringing deplorable working conditions to the attention of the general public. Public awareness and, in some cases, outrage eventually led to these **employer-biased laws** being overturned in all states except one. In New Hampshire, the fellow servant rule still applies.

West Fertilizer Company Explosion

On April 17, 2013, an explosion occurred at the storage and distribution center of the West Fertilizer Company in West, Texas. The explosion occurred when fire set off ammonium nitrate while emergency personnel were battling the blaze. The explosion killed 15 people and injured 160 others. More than 150 surrounding buildings were damaged or destroyed. In the ensuing investigation, it was determined that the fire had been deliberately set. Prior to the fire and explosion, OSHA had fined the company for improper storage of anhydrous ammonia and cited the company for violating its respiratory protection standards. The company had also been fined by the Environmental Protection Agency (EPA) in 2006 for failing to file a risk management program plan in a timely manner. Further, the company had been fined in 2012 by the U.S. Department of Transportation for violations pertaining to the improper storage of anhydrous ammonia.

ROLE OF SPECIFIC HEALTH PROBLEMS

Specific health problems that have been tied to workplace hazards have played significant roles in the development of the modern safety and health movement. These health problems contributed to public awareness of dangerous and unhealthy working conditions that, in turn, led to legislation, regulations, better work procedures, and better working conditions.

Lung disease in coal miners was a major problem in the 1800s, particularly in Great Britain, where much of the Western world's coal was mined at the time. Frequent contact with coal dust led to a widespread outbreak of anthracosis among Great Britain's coal miners. Also known as the *black spit*, this disease persisted from the early 1800s, when it was first identified, until around 1875, when it was finally eliminated by such safety and health measures as ventilation and decreased work hours.

In the 1930s, Great Britain saw a resurgence of lung problems among coal miners. By the early 1940s, British scientists were using the term *coal-miner's pneumoconiosis*, or CWP, to describe a disease from which many miners suffered. Great Britain designated CWP a separate and compensable disease in 1943. However, the United States did not immediately follow suit, even though numerous outbreaks of the disease had occurred among miners in this country.

The issue was debated in the United States until Congress finally passed the Coal Mine Health and Safety Act in 1969. The events that led up to the passage of this act were tragic. An explosion in a coal mine in West Virginia in 1968 killed 78 miners. This tragedy focused attention on mining health and safety, and Congress responded by passing the Coal Mine Health and Safety Act. The act was amended in 1977 and again in 1978 to broaden the scope of its coverage.

Over the years, the diseases suffered by miners were typically lung diseases caused by the inhalation of coal dust particulates. However, health problems were not limited to coal miners. Other types of miners developed a variety of diseases, the most common of which was silicosis. Once again, it took a tragic event—the Gauley Bridge disaster, discussed earlier—to focus attention on a serious workplace problem.

Congress held a series of hearings on the matter in 1936. That same year, representatives from business, industry, and government attended the National Silicosis Conference, convened by the U.S. secretary of labor. Among other outcomes of this conference was a finding that silica dust particulates did, in fact, cause silicosis.

Mercury poisoning is another health problem that has contributed to the evolution of the safety and health movement by focusing public attention on unsafe conditions in the workplace. The disease was first noticed among the citizens of a Japanese fishing village in the early 1930s. A disease with severe symptoms was common in Minamata, but extremely rare throughout the rest of Japan. After much investigation into the situation, it was determined that a nearby chemical plant periodically dumped methyl mercury into the bay that was the village's primary source of food. Consequently, the citizens of this small village ingested hazardous dosages of mercury every time they ate fish from the bay.

Mercury poisoning became an issue in the United States after a study was conducted in the early 1940s that focused on New York City's hat-making industry. During that time, many workers in this industry displayed the same types of symptoms as the citizens of Minamata, Japan. Because mercury nitrate was used in the production of

hats, enough suspicion was aroused to warrant a study. The study linked the symptoms of workers with the use of mercury nitrate. As a result, the use of this hazardous chemical in the hat-making industry was stopped, and a suitable substitute—hydrogen peroxide—was found.

As discussed earlier, asbestos was another important substance in the evolution of the modern safety and health movement. By the time it was determined that asbestos is a hazardous material, the fibers of which can cause asbestosis or lung cancer (mesothelioma), thousands of buildings contained the substance. As these buildings began to age, the asbestos—particularly that used to insulate pipes—began to break down. As asbestos breaks down, it releases dangerous microscopic fibers into the air. These fibers are so hazardous that removing asbestos from old buildings has become a highly specialized task requiring special equipment and training.

More recently, concern over the potential effects of bloodborne pathogens in the workplace has had a significant impact on the safety and health movement. Diseases such as acquired immunodeficiency syndrome (AIDS) and pathogens such as human immunodeficiency virus (HIV) and Hepatitis B (HBV) have caused changes to how safety and health professionals respond to medical emergencies and injuries in which blood and other bodily fluids may be present. Concern over the potential effects of bloodborne pathogens has introduced a whole new set of precautions as well as fears—some rational and some irrational—into the realm of workplace safety. Chapter 20 is devoted to the concept of bloodborne pathogens as it relates to workplace safety.

SAFETY AND HEALTH STANDARDS APPLY TO MORE THAN JUST MANUFACTURING

There is a misconception in some quarters that safety and health procedures such as those presented in this book apply only to manufacturing. While it is important for employers in the manufacturing sector to provide a safe and healthy work environment for their personnel, it is equally important for employers in all work sectors to do the same. The safe and healthy work practices advocated in this book apply to all work sectors, including natural resources and mining, manufacturing, construction, services, trade, transportation, utilities, information, financial, professional and business, education, government, healthcare, maritime, leisure, retail, and hospitality. As you will learn in Chapter 5, certain industry sectors such as construction and maritime have their own specific safety and health standards. But other sectors are covered by the rules set forth in 29 CFR 1910, OSHA's General Industry Standard.

DEVELOPMENT OF ACCIDENT PREVENTION PROGRAMS

In the modern workplace, there are many different types of **accident prevention** programs ranging from the simple to the complex. Widely used accident prevention techniques include failure minimization, fail-safe designs, isolation, lockouts, screening, personal protective equipment, redundancy, timed replacements, and many others. These techniques are individual components of broader safety programs. Such programs have evolved since the late 1800s.

In the early 1800s, employers had little concern for the safety of workers and little incentive to be concerned. Consequently, organized safety programs were nonexistent, a situation that continued for many years. However, between World War I and World War II, industry discovered the connection between quality and safety. Then, during World War II, troop call-ups and deployments created severe labor shortages. Faced with these shortages, employers could not afford to lose workers to accidents or for any other reason. This realization created a greater openness toward giving safety the serious consideration that it deserved. For example, according to the Society of Manufacturing Engineers (SME), around this time industry began to realize the following:

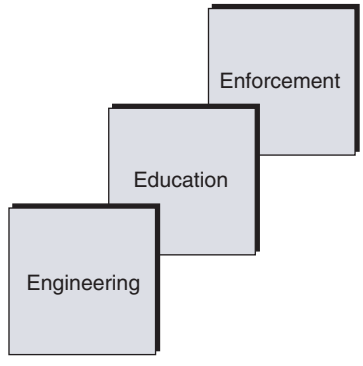
- Improved engineering could prevent accidents.
- Employees were willing to learn and accept safety rules.
- Safety rules could be established and enforced.
- Financial savings from safety improvement could be reaped by savings in compensation and medical bills.[17]

With these realizations came the long-needed incentive for employers to begin playing an active role in creating and maintaining a safe workplace. This, in turn, led to the development of organized safety programs sponsored by management. Early safety programs were based on the **three E's of safety**: Engineering, Education, and Enforcement (see Figure 1–2). The engineering aspects of a safety program involve making design improvements to both product and process. By altering the design of a product, the processes used to manufacture it can be simplified and, as a result, made less dangerous. In addition, the manufacturing processes for products can be engineered in ways that decrease potential hazards associated with the processes.

The education aspect of a safety program ensures that employees know how to work safely, why it is important to do so, and that safety is expected by management. Safety education typically covers the what, when, where, why, and how of safety.

The enforcement aspect of a safety program involves making sure that employees abide by safety policies, rules, regulations, practices, and procedures. Supervisors and fellow employees play a key role in the enforcement aspects of modern safety programs.

FIGURE 1–2 Three E's of safety.



DEVELOPMENT OF SAFETY ORGANIZATIONS

Today, numerous organizations are devoted in full, or at least in part, to the promotion of safety and health in the workplace. Figure 1–3 lists organizations with workplace safety as part of their missions. Figure 1–4 lists several governmental agencies and two related organizations concerned with safety and health. These lists are extensive now, but this has not always been the case. Safety organizations in this country had humble beginnings.

The grandfather of them all is the NSC. The SME traces the genesis of this organization as follows:

> The Association of Iron and Steel Electrical Engineers was organized in the first decade of the 20th century and devoted much attention to safety problems in its industry. In 1911, a request came from this association to call a national industrial safety conference. The first Cooperative Safety Congress met in Milwaukee in 1912. A year later, at a meeting in New York City, the National Council of Industrial Safety was formed. It began operation in a small office in Chicago. At its meeting in 1915, the organization's name was changed to the National Safety Council (NSC).[18]

Today, the NSC is the largest organization in the United States devoted solely to safety and health practices and procedures. Its purpose is to prevent the losses, both

FIGURE 1–3 Organizations concerned with workplace safety.

- Alliance for American Insurers
- American Board of Industrial Hygiene
- American Conference of Government Industrial Hygienists
- American Industrial Hygiene Association
- American Insurance Association
- American National Standards Institute
- American Occupational Medical Association
- American Society for Testing and Materials
- American Society of Mechanical Engineers
- American Society of Safety Engineers
- Chemical Transportation Emergency Center
- Human Factors Society
- National Fire Protection Association
- National Safety Council
- National Safety Management Society
- Society of Automotive Engineers
- System Safety Society
- Underwriters Laboratories, Inc.

FIGURE 1–4 Government agencies and other organizations concerned with workplace safety.

American Public Health Association*
Bureau of Labor Statistics
Bureau of National Affairs
Commerce Clearing House*
Environmental Protection Agency
National Institute for Standards and Technology (formerly National Bureau of Standards)
National Institute for Occupational Safety and Health
Occupational Safety and Health Administration
Superintendent of Documents, U.S. Government Printing Office
U.S. Consumer Product Safety Commission
*Not a government agency.

direct and indirect, arising out of accidents or from exposure to unhealthy environments. Although it is chartered by an act of Congress, the NSC is a nongovernmental, not-for-profit, public service organization.

The **Occupational Safety and Health Administration (OSHA)** is the government's administrative arm for the Occupational Safety and Health Act (OSH Act). Formed in 1970, OSHA sets and revokes safety and health standards, conducts inspections, investigates problems, issues citations, assesses penalties, petitions the courts to take appropriate action against unsafe employers, provides safety training, provides injury prevention consultation, and maintains a database of health and safety statistics.

Another governmental organization is the **National Institute for Occupational Safety and Health (NIOSH)**. This organization is part of the Centers for Disease Control and Prevention (CDC) of the Department of Health and Human Services. NIOSH is required to publish annually a comprehensive list of all known toxic substances. NIOSH will also provide on-site tests of potentially toxic substances so that companies know what they are handling and what precautions to take.

An organization of note is the **Chemical Safety Board (CSB)**. The CSB is a federal agency charged with the responsibility to investigate industrial chemical accidents. The CSB conducts root cause analyses of chemical accidents that occur at fixed-site facilities (as opposed to accidents involving chemicals that are being transported). The agency does not issue fines or citations, but does make recommendations to OSHA and the EPA. CSB is independent of these and other regulatory agencies, so its investigations can be used to measure the effectiveness of regulations relating to chemical safety.

SAFETY AND HEALTH MOVEMENT TODAY

The safety and health movement has come a long way since the Industrial Revolution. Today, there is widespread understanding of the importance of providing a safe and healthy workplace. The tone was set during and after World War II when all the various practitioners of occupational health and safety began to see the need for cooperative efforts. These practitioners included safety engineers, safety managers, industrial hygienists, occupational health nurses, and physicians. Integration has led to better sharing of knowledge among these practitioners concerning safety and health problems in the workplace, brought a greater level of expertise to bear on evaluating the causes of safety and health problems, generated a large and growing database of helpful information about safety and health problems, enhanced the focus on accident prevention, and encouraged employers to make safety and health a high priority.

INTEGRATED APPROACH TO SAFETY AND HEALTH

The integrated approach has become the norm that typifies the safety and health movement of today. By working together and drawing on their own respective areas of expertise, safety and health professionals are better able to identify, predict, control, and correct safety and health problems.

OSHA reinforces the integrated approach by requiring companies to have a plan for doing at least the following: (1) providing appropriate medical treatment for injured or ill workers, (2) regularly examining workers who are exposed to toxic substances, and (3) having a qualified first-aid person available during all working hours.

Smaller companies may contract out the fulfillment of these requirements. Larger companies often maintain a staff of safety and health professionals. The safety and health staff of a modern company can now include such positions as safety engineer, safety manager, ergonomist, industrial hygiene professionals, **radiation control specialists**, occupational nurses, physicians, psychologists, counselors, educators, and dieticians.

NEW MATERIALS, NEW PROCESSES, AND NEW PROBLEMS

The job of the safety and health professional is more complex than it has ever been. The materials out of which products are made have become increasingly complex and exotic. Engineering metals now include carbon steels, alloy steels, high-strength low-alloy steels, stainless steels, managing steels, cast steels, cast irons, tungsten, molybdenum, titanium, aluminum, copper, magnesium, lead, tin, zinc, and powdered metals. Each of these metals requires its own specialized processes.

Nonmetals are more numerous and have also become more complex. Plastics, plastic alloys and blends, advanced composites, fibrous materials, elastomers, and ceramics also bring their own potential hazards to the workplace.

In addition to the more complex materials being used in modern industry and the new safety and health concerns associated with them, modern industrial processes are also becoming more complex. As these processes become automated, the potential hazards associated with them often increase. Computers; lasers; industrial robots; non-traditional processes such as explosive welding, photochemical machining, laser beam machining, ultrasonic machining, and chemical milling; automated material handling; water-jet cutting expert systems; flexible manufacturing cells; and computer-integrated manufacturing have all introduced new safety and health problems in the workplace and new challenges for the safety and health professional.

RAPID GROWTH IN THE PROFESSION

The complexities of the modern workplace have made safety and health a growing profession. Associate and baccalaureate degree programs in industrial technology typically include industrial safety courses. Some engineering degree programs have safety and health tracks. Several colleges and universities offer full degrees in occupational safety and health.

The inevitable result of the increased attention given to safety and health is that more large companies are employing safety and health professionals and more small companies are assigning these duties to existing employees. This is a trend that is likely to continue as employers see their responsibilities for safety and health spread beyond the workplace to the environment, the community, the users of their products, and the recipients of their by-products and waste.

DOES MOVING MANUFACTURING JOBS OVERSEAS REDUCE THE ACCIDENT RATE?

If you would like to start a debate among occupational safety and health professionals, ask this question: Is moving manufacturing jobs overseas reducing the accident rate in America? Some say "yes" and others say "no." Here are some facts:

- Over the past decade, thousands of jobs in the manufacturing sector have migrated to China, India, Malaysia, Pakistan, and other countries that maintain low labor rates.
- Since 2003, the recordable injury and illness rate has declined in the United States every year.
- The largest year-to-year declines have been in the manufacturing sector. However, even the construction industry has seen declines during the same time period and those jobs are not being exported.

Some claim that the workplace accident rate is declining because America has *exported* its accidents along with its jobs, particularly in the manufacturing sector. Others claim that the declines can be attributed to more and better safety and health regulations, oversight, education, and enforcement. The more likely scenario is that both the loss of manufacturing jobs to foreign countries and better safety and health practices have contributed to the decline.

Key Terms and Concepts

- Accident prevention
- Asbestos menace
- Assumption of risk
- Bhopal tragedy
- Chemical Safety Board (CSB)
- Code of Hammurabi
- Contributory negligence
- Cooperative Safety Congress (CSC)
- Employer-biased laws
- Employer liability
- Fellow servant rule
- Hawk's Nest tragedy
- Inanimate power
- National Council of Industrial Safety (NCIS)
- National Institute for Occupational Safety and Health (NIOSH)
- Occupational Safety and Health Act (OSH Act)
- Occupational Safety and Health Administration (OSHA)
- Organized labor
- Radiation control specialists
- Safety movement
- Three E's of safety
- West Fertilizer Company Explosion
- Workers' compensation

Review Questions

1. To what cause(s) can the improvements in workplace safety made to date be attributed?
2. Explain the significance of the Code of Hammurabi in terms of the safety movement.
3. Describe the circumstances that led to the development of the first organized safety program.
4. What is Frederick Taylor's connection to the safety movement?
5. Explain the development of the National Safety Council.
6. What impact did labor shortages in World War II have on the safety movement?
7. Explain how workplace tragedies have affected the safety movement. Give examples.
8. Explain the primary reasons behind the passage of the OSH Act.
9. Summarize briefly the role that organized labor has played in the advancement of the safety movement.
10. Define the following terms: fellow servant rule, contributory negligence, and assumption of risk.
11. Explain the three E's of safety.
12. Explain the term *integration* as it relates to modern safety and health.

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CHAPTER

2 ACCIDENTS AND THEIR EFFECTS

Learning Objectives

- Summarize the cost of accidents in the United States
- Summarize the figures for accidents and deaths in the United States
- Compare workplace deaths with other causes of deaths in the United States
- Describe the costs of workplace accidents
- Explain the amount of time that is lost in the workplace because of accidents
- Summarize the figures for deaths that occur in workplace accidents
- Categorize workplace injuries by type of accident
- Categorize death rates according to industry
- Summarize the figures for injuries to different body parts in the workplace
- Explain how to estimate the cost of accidents
- Describe the global impact of accidents and injuries in the workplace
- Describe the types of accident/injury reports and logs required by OSHA

There is a long history of debate in this country concerning the effect of **accidents** on industry (the workers and the companies) and the cost of preventing accidents. Historically, the prevailing view was that **accident prevention** programs were too costly. The more contemporary view is that accidents are too costly and that accident prevention makes sense economically. As a result, accident prevention, which had been advocated on a moral basis, is now justified in economic terms.

Accidents are the fourth leading cause of death in this country after heart disease, cancer, and strokes. This ranking is based on all types of accidents, including motor vehicle accidents, drownings, fires, falls, natural disasters, and work-related accidents.

Although deaths from **natural disasters** tend to be more newsworthy than workplace deaths, their actual impact is substantially less. For example, natural disasters in the

FIGURE 2–1 Approximate accident costs (in dollars) by accident type (in billions, 2017).

Motor vehicle accidents	$72.5
Workplace accidents	50
Home accidents	20
Public accidents	13

United States cause fewer than 100 deaths per year on average. **Workplace accidents**, on the other hand, cause more than 10,000 deaths every year in the United States.[1]

This chapter provides prospective and practicing **safety and health professionals** with the information they need to have a full understanding of workplace accidents and their effect on industry in the United States. Such an understanding will help professionals play a more effective role in keeping both management and labor focused appropriately on safety and health in the workplace.

COSTS OF ACCIDENTS

To gain a proper perspective on the economics of workplace accidents, we must view them in the overall context of all accidents. The overall cost of accidents in the United States is approximately $155 billion. These costs include such factors as **lost wages**, **medical expenses**, **insurance administration**, **fire-related losses**, motor vehicle **property damage**, and **indirect costs**.

Figure 2–1 breaks down this overall amount by categories of accidents. Figure 2–2 breaks them down by cost categories. Notice in Figure 2–1 that workplace accidents rank second behind motor vehicle accidents in cost. Figure 2–2 shows that the highest cost category is wages lost by workers who are either injured or killed. The category of indirect losses from work accidents consists of costs associated with responding to accidents (i.e., giving first aid, filling out accident reports, and handling production slowdowns).

Clearly, accidents on and off the job cost the U.S. industry dearly. Every dollar that is spent responding to accidents is a dollar that could have been reinvested in modernization, research and development, facility upgrades, and other competitiveness-enhancing activities.

FIGURE 2–2 Approximate accident costs by categories, 2017.

Wages lost	$40
Medical expenses	25
Insurance administration	30
Property damage (motor vehicle)	30
Fire losses	10
Indirect losses for work accidents	40

ACCIDENTAL DEATHS IN THE UNITED STATES

Accidental deaths in the United States result from a variety of causes, including motor vehicle accidents, falls, poisoning, drowning, fire-related injuries, **suffocation** (ingested object), firearms, medical complications, air transport accidents, interaction with machinery, mechanical suffocation, and the impact of falling objects. The National Safety Council (NSC) periodically computes death totals and death rates in each of these categories. The statistics for a typical year are as follows:

- **Motor vehicle accidents.** Motor vehicle accidents are the leading cause of accidental deaths in the United States each year. They include deaths resulting from accidents involving mechanically or electrically powered vehicles (excluding rail vehicles) that occur on or off the road. In a typical year, there are approximately 47,000 such deaths in the United States.
- **Falls.** This category includes all deaths from **falls** except those associated with transport vehicles. For example, a person who is killed as the result of falling while boarding a bus or train would not be included in this category. In a typical year, there are approximately 13,000 deaths in the United States from falls.
- **Poisoning.** The **poisoning** category is divided into two subcategories: (1) poisoning by solids and liquids and (2) poisoning by gases and vapors. The first category includes deaths that result from the ingestion of drugs, medicine, widely recognized solid and liquid poisons, mushrooms, and shellfish. It does not include poisoning from spoiled food or salmonella. The second category includes deaths caused by incomplete combustion (e.g., gas vapors from an oven or unlit pilot light) or from carbon monoxide (e.g., exhaust fumes from an automobile). In a typical year, there are approximately 6,000 deaths in the first category and 1,000 in the second.
- **Drowning.** This category includes work-related and non-work-related **drownings** but excludes those associated with floods or other natural disasters. In a typical year, there are approximately 5,000 deaths from drowning in the United States.
- **Fire-related injuries.** This category includes deaths from burns, asphyxiation, falls, and those that result from falling objects in a fire. In a typical year, there are more than 4,000 fire-related deaths in the United States.
- **Suffocation (ingested object).** This category includes deaths from the ingestion of an object that blocks the air passages. In many such deaths, the ingested object is food. In a typical year, there are approximately 4,000 suffocation deaths in the United States.
- **Firearms.** This category includes deaths that result when recreational activities involving firearms or household accidents involving firearms result in death. For example, a person killed in the home while cleaning a firearm would be included in this category. However, a person killed in combat would not be included. In a typical year, there are approximately 2,000 such deaths in the United States.
- **Others.** This category includes deaths resulting from **medical complications** arising out of mistakes made by healthcare professionals, air transport injuries, interaction with machinery, **mechanical suffocation**, and the impact of falling objects. In a typical year, there are more than 14,000 deaths in these subcategories.[2]

FIGURE 2–3 Causes of accidents (ages 25–44 years, 2017).

Accidents	30,000
Cancer	21,000
Motor vehicle	17,000
Heart disease	16,000
Poison (solid, liquid)	3,000
Drowning	1,500
Falls	1,200
Fire related	1,000

ACCIDENTS VERSUS OTHER CAUSES OF DEATH

Although there are more deaths every year from **heart disease**, **cancer**, and **strokes** than from accidents, these causes tend to be concentrated among people at or near retirement age. Among people 37 years of age or younger—prime working years—accidents are the number one cause of death. Figure 2–3 summarizes the causes of death for persons from 25 to 44 years of age. Notice that the leading cause is accidents.

Figure 2–3 shows that accidents represent a serious detriment to productivity, quality, and competitiveness in today's workplace. Yet accidents are the one cause of death and injury that companies can most easily control. Although it is true that companies may have some success in decreasing the incidence of heart disease and stroke among their employees through such activities as corporate wellness programs, their impact in this regard is limited. However, employers can have a significant impact on preventing accidents.

WORK ACCIDENT COSTS AND RATES

Workplace accidents cost employers millions every year. Consider the following examples from the recent past. ARCO Chemical Company was ordered to pay $3.48 million in fines as a result of failing to protect workers from an explosion at its petrochemical plant in Channelview, Texas. The steel-making division of USX paid a $3.25 million fine to settle numerous health and safety violation citations. BASF Corporation agreed to pay a fine of $1.06 million to settle Occupational Safety and Health Administration (OSHA) citations associated with an explosion at a Cincinnati chemical plant that caused two deaths and 17 injuries.

These examples show the costs of fines only. In addition to fines, these employers incurred costs for safety corrections, medical treatment, survivor benefits, death and burial costs, and a variety of indirect costs. Clearly, work accidents are expensive. However, the news is not all bad. The trend in the rate of accidents is downward.

Work **accident rates** in this century are evidence of the success of the safety movement in the United States. As the amount of attention given to workplace safety and health has increased, the accident rate has decreased.

As Figure 2–1 shows, the cost of these 10,000 work deaths and work injuries was $50 billion. This translates into a cost of $500 per worker in the United States, computed as the value-add required per worker to offset the cost of work injuries.

Although statistics are not available to document the supposition, many safety and health professionals believe that the major cost of accidents and injuries on the job results from damage to morale. Employee morale is a less tangible factor than documentable factors such as lost time and medical costs. However, it is widely accepted among management professionals that few factors affect productivity more than employee morale. Employees with low morale do not produce up to their maximum potential. This is why so much time and money are spent every year to help supervisors and managers learn different ways to help improve employee morale.

Because few things are as detrimental to employee morale as seeing a fellow worker injured, accidents can have a devastating effect on morale. Whenever an employee is injured, his or her colleagues silently think, "That could have been me," in addition to worrying about the employee. Morale is damaged even more if the injured employee is well-liked and other employees know his or her family.

TIME LOST BECAUSE OF WORK INJURIES

An important consideration when assessing the effect of accidents on industry is the amount of **lost time** due to **work injuries**.[3] According to the NSC, approximately 35 million hours are lost in a typical year as a result of accidents. This is actual time lost from disabling injuries and does not include additional time lost for medical checkups after the injured employee returns to work. Accidents that occurred in previous years often continue to cause lost time in the current year.

DEATHS IN WORK ACCIDENTS

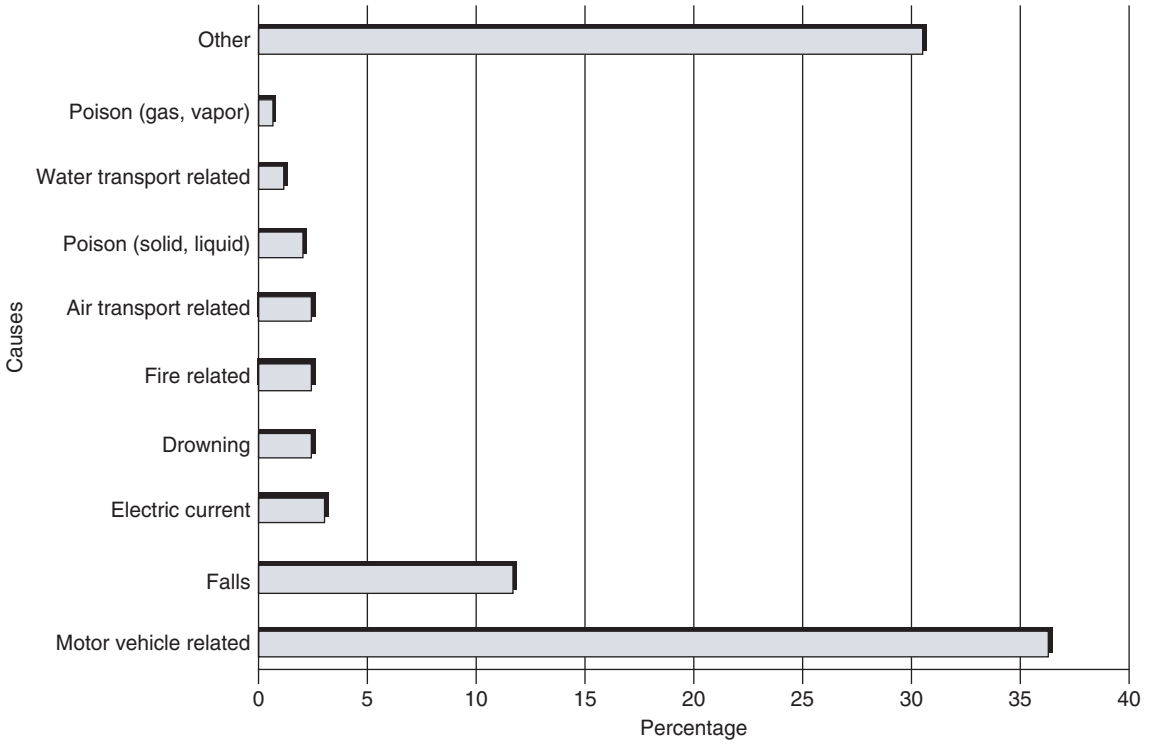
Deaths on the job have decreased markedly over the years. However, they still occur. For example, in a typical year, there are 10,400 work deaths in the United States. The causes of death in the workplace vary. They include those related to motor vehicles, falls, electric current, drowning, fires, air transport, poisoning, water transport, machinery, falling objects, rail transport, and mechanical suffocation.[4] Figure 2–4 gives a complete breakdown of the percentages for the various categories of causes.

WORK INJURIES BY TYPE OF ACCIDENT

Work injuries can be classified by the type of accident from which they resulted. The most common causes of work injuries are as follows:

- Overexertion
- Impact accidents
- Falls
- Bodily reaction (to chemicals)
- Compression

FIGURE 2–4 Work deaths by cause for a typical year.



- Motor vehicle accidents
- Exposure to radiation or caustics
- Rubbing or abrasions
- Exposure to extreme temperatures

Overexertion, the result of employees working beyond their physical limits, is the leading cause of work injuries. According to the NSC, almost 31 percent of all work injuries are caused by overexertion. **Impact accidents** involve a worker being struck by or against an object. The next most prominent cause of work injuries is falls.[5] The remaining accidents are distributed fairly equally among the other causes listed above.

DEATH RATES BY INDUSTRY

A variety of agencies and organizations, including the Bureau of Labor Statistics, the National Center for Health Statistics, and the NSC, collect data on **death rates** within industrial categories.[6] Such information can be used in a variety of ways, not the least of which is in assigning workers' compensation rates. The most widely used industrial categories are agriculture, including farming, forestry, and fishing; mining/quarrying, including oil and gas drilling and extraction; construction; manufacturing;

transportation/public utilities; trade, both wholesale and retail; services, including finance, insurance, and real estate; and federal, state, and local governments.

The rate of fatalities across all occupations fluctuates somewhat from year to year and from industry to industry. However, the rate of 3.5 fatalities per year per 100,000 workers holds fairly constant over time. The greater fluctuation is in the industry sector that experiences the most fatalities in a given year. The following order of ranking will change from year to year, but the industry sectors that comprise the top sectors by annual death rate remain fairly constant. Occupations that typically have the highest rate of fatalities on the job are as follows (not necessarily in order since the order changes every year):

- Fishing
- Logging
- Mining/quarrying
- Agriculture
- Construction
- Transportation and warehousing
- Manufacturing
- Aircraft pilots, flight engineers, and maintenance
- Refuse and recycling collectors
- Law enforcement
- Professional and business services
- Retail
- Public administration/government

Figures for costs, work-related deaths, accidents, and so on change over time. For the most up-to-date figures, go to the website of the Bureau of Labor Statistics: www.bls.gov

PARTS OF THE BODY INJURED ON THE JOB

To develop and maintain an effective safety and health program, it is necessary to know not only the most common causes of death and injury but also the parts of the body most frequently injured. The NSC stated the following:

> Disabling work injuries in the entire nation totaled approximately 1.75 million in 1998. Of these, about 10,400 were fatal and 60,000 resulted in some permanent impairment. Injuries to the back occurred most frequently, followed by thumb and finger injuries and leg injuries.[7]

Typically, the most frequent injuries to specific parts of the body are as follows (from most frequent to least):

1. Back
2. Legs and fingers
3. Arms and multiple parts of the body
4. Trunk
5. Hands
6. Eyes, head, and feet
7. Neck, toes, and body systems

The back is the most frequently injured part of the body. Legs and fingers are injured with approximately the same frequency, as are arms and multiple parts of the body; the hands are next in frequency, followed by the eyes, the head, and feet; and neck, toes, and body systems. This ranking shows that one of the most fundamental components of a safety and health program should be instruction on how to lift without hurting the back (see Chapter 11).

ESTIMATING THE COST OF ACCIDENTS

Even decision makers who support accident prevention must consider the relative costs of such efforts. Clearly, accidents are expensive. However, to be successful, safety and health professionals must be able to show that accidents are more expensive than prevention. To do this, they must be able to estimate the cost of accidents. The procedure for estimating costs set forth in this section was developed by Professor Rollin H. Simonds of Michigan State College working in conjunction with the Statistics Division of the NSC.

Cost-Estimation Method

Professor Simonds states that in order to have value, a cost estimate must relate directly to the specific company in question. Applying broad industry cost factors will not suffice. To arrive at company-specific figures, Simonds recommends that costs associated with an accident be divided into *insured* and *uninsured* costs.[8]

Determining the insured costs of accidents is a simple matter of examining accounting records. The next step involves calculating the uninsured costs. Simonds recommends that accidents be divided into the following four classes:

- **Class 1 accidents.** Lost workdays, permanent partial disabilities, and temporary total disabilities.
- **Class 2 accidents.** Treatment by a physician outside the company's facility.
- **Class 3 accidents.** Locally provided first aid, property damage of less than $100, or the loss of less than eight hours of work time.
- **Class 4 accidents.** Injuries that are so minor that they do not require the attention of a physician, result in property damage of $100 or more, or cause eight or more work hours to be lost.[9]

Average uninsured costs for each class of accident can be determined by pulling the records of all accidents that occurred during a specified period and by sorting the records according to class. For each accident in each class, record every cost that was not covered by insurance. Compute the total of these costs by class of accident and divide by the total number of accidents in that class to determine an average uninsured cost for each class, specific to the particular company.

Figure 2–5 is an example of how the average cost of a selected sample of Class 1 accidents can be determined. In this example, there were four Class 1 accidents in the pilot test. These four accidents cost the company a total of $554.23 in uninsured costs, or an average of $138.56 per accident. Using this information, accurate cost estimates of an accident can be figured, and accurate predictions can be made.

FIGURE 2–5 Uninsured costs worksheet.

Class of Accident	Accident Number							
Class 1	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cost A	$ 16.00	$ 6.95	$ 15.17	$ 3.26				
Cost B	72.00	103.15	97.06	51.52				
Cost C	26.73	12.62	—	36.94				
Cost D	—	51.36	—	38.76				
Cost E	—	11.17	—	24.95				
Cost F	—	—	—	–13.41				
Cost G	—	—	—	—				
Total	114.73	185.25	112.23	142.02				

Grand Total: $554.23

Average Cost per Accident: $138.56 (Grand Total ÷ Number of Accidents)

Signature: _____ Date: _____

Other Cost-Estimation Methods

The costs associated with workplace accidents, injuries, and incidents fall into broad categories such as the following:

- Lost work hours
- Medical costs
- Insurance premiums and administration
- Property damage
- Fire losses
- Indirect costs

Calculating the direct costs associated with lost work hours involves compiling the total number of lost hours for the period in question and multiplying the hours times the applicable loaded labor rate. The loaded labor rate is the employee's hourly rate plus benefits. Benefits vary from company to company but typically inflate the hourly wage by 20–35 percent. A sample cost-of-lost-hours computation follows:

$$\text{Employee Hours Lost (4th quarter)} \times \text{Average Loaded Labor Rate} = 386 \times 13.48 = \$5{,}203.28$$

In this example, the company lost 386 hours due to accidents on the job in the fourth quarter of its fiscal year. The employees who actually missed time at work formed a pool of people with an average loaded labor rate of $13.48 per hour ($10.78 average hourly wage plus 20 percent for benefits). The average loaded labor

rate multiplied by the 386 lost hours reveals an unproductive cost of $5,203.28 to this company.

By studying records that are readily available in the company, a safety professional can also determine medical costs, insurance premiums, property damage, and fire losses for the time period in question. All these costs taken together result in a subtotal cost. This figure is then increased by a standard percentage to cover indirect costs to determine the total cost of accidents for a specific time period. The percentage used to calculate indirect costs can vary from company to company, but 20 percent is a widely used figure.

Estimating Hidden Costs

Safety professionals often use the *iceberg analogy* when talking about the real costs of accidents. Accident costs are like an iceberg in that their greatest portion is hidden from view.[10] In the case of icebergs, the larger part is hidden beneath the surface of the water. In the case of an accident, the larger part of the actual cost is also hidden beneath the surface.

There are many different models that can be used for estimating both the direct and indirect costs of accidents. Some of these models are so complex that their usefulness is questionable. The checklist in Figure 2–6 is a simple and straightforward tool that can be used to estimate the hidden costs of accidents.

FIGURE 2–6 Some accident costs that might be overlooked.

Checklist for

Estimating the Hidden Costs of Accidents

√	Paid time to the injured employee on the day of the accident.
√	Paid time of any emergency-responder personnel involved (including ambulance driver).
√	Paid time of all employees who were interviewed as part of the accident investigation.
√	Paid time of the safety personnel who conducted the accident investigation.
√	Paid time of the human resources personnel who handled the workers' compensation and medical aspects of the accident.
√	Paid time of the supervisor involved in the accident investigation and accident response.
√	Paid time to employees near the accident working (or slowed down) temporarily as a result of the accident.
√	Paid time to employees who spent time talking about the accident as news of it spread through the company's grapevine.

GLOBAL IMPACT OF ACCIDENTS AND INJURIES

According to the International Labour Organization (ILO) of the United Nations, approximately 2.2 million people die every year of work-related injuries and occupational diseases.[11] Actually, due to poor record keeping and reporting in underdeveloped countries, it is estimated that this figure is low. Rapid development and the pressure of global competition are resulting in increased workplace fatalities in China and the Pacific Rim countries.

What is missing in many of the developing countries that are becoming industrialized is a safety and health infrastructure. Such an infrastructure would include government-enforced safety and health regulations, company-sponsored safety and health training, record-keeping and reporting systems, and management practices that make occupational safety and health a fully integrated component of work processes and the competitive philosophy of organizations. Occupational safety and health must come to be seen as a strategy for sustaining economic growth and social development in emerging countries.

There is much to be done if developing countries are going to provide safe and healthy working conditions for their citizens. The ILO reports:

- Record-keeping and reporting systems in developing countries are deteriorating instead of improving. Consequently, only a fraction of the real toll of workplace accidents and injuries is being reported.
- Men in developing countries tend to die as the result of accidents, lung diseases, and work-related cancers such as those caused by asbestos. Women in developing countries suffer more from musculoskeletal disorders, communicable diseases, and psychosocial problems.
- Occupational injuries in developing countries are more prevalent in such high-risk industries as mining, construction, and agriculture.
- Younger workers in developing countries are more likely to suffer nonfatal injuries, while older workers are more likely to suffer fatal injuries.
- In developing countries, more than half of retirements are taken early to collect pensions based on work-related disabilities rather than normal retirement.

OSHA REPORTS AND LOGS

Accident investigation and reporting are important aspects of the safety professional's responsibilities. OSHA has specific requirements concerning accident reporting and specific logs for making reports. Safety professionals must know how to complete OSHA logs 300, 300A, and 301, when to use each log, how to submit these logs, and when to submit them. OSHA Form 300 is a log of work-related injuries and illnesses. OSHA Form 300A is a summary report of work-related injuries and illnesses. OSHA Form 301 is used to report individual incidents of injuries and illnesses. The concept of using OSHA reports and logs is introduced here only for informational purposes. Readers will learn all of OSHA's requirements for accident reporting as which forms to use, how to complete them, and when to submit them in Chapter 5.

Accident rates are especially high in developing countries because these countries are responding to the pressures of global competition without first putting a safety and health infrastructure in place (e.g., regulations, training, and record keeping).

Key Terms and Concepts

- Accident prevention
- Accident rates
- Accidents
- Cancer
- Death rates
- Drownings
- Falls
- Fire-related losses
- Heart disease
- Impact accidents
- Indirect costs
- Insurance administration
- Lost time
- Lost wages
- Mechanical suffocation
- Medical complications
- Medical expenses
- Natural disasters
- Overexertion
- Poisoning
- Property damage
- Safety and health professionals
- Strokes
- Suffocation
- Work injuries
- Workplace accidents

Review Questions

1. What are the leading causes of death in the United States?
2. When the overall cost of an accident is calculated, what elements make up the cost?
3. What are the five leading causes of accidental deaths in the United States?
4. What are the leading causes of death in the United States of people between the ages of 25 and 44?
5. Explain how today's rate of accidental work deaths compares with the rate in the early 1900s.
6. What are the five leading causes of work deaths?
7. What are the five leading causes of work injuries by type of accident?
8. When death rates are classified by industry type, what are the three leading industry types?
9. Rank the following body parts according to frequency of injury from highest to lowest: neck, fingers, trunk, back, and eyes.
10. Explain the reasons for high accident rates in developing countries.

Endnotes

1. National Safety Council, *Accident Facts* (Chicago: National Safety Council, 2017), 37.
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7. Ibid., 38.
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CHAPTER

3 THEORIES OF ACCIDENT CAUSATION

Learning Objectives

- Explain the Domino Theory of accident causation
- Explain the Human Factors Theory of accident causation
- Explain the Accident/Incident Theory of accident causation
- Explain the Epidemiological Theory of accident causation
- Explain the Systems Theory of accident causation
- Explain the Combination Theory of accident causation
- Explain the Behavioral Theory of accident causation
- Describe the individual factors that can be part of accident causation
- Describe how depression can play a role in accident causation
- Summarize how management failures can play a role in accident causation
- Describe how obesity can be a factor in accident causation
- Explain the Swiss Cheese Model and how it relates to accident causation

Each year, work-related accidents cost the United States almost $50 billion.[1] This figure includes costs associated with lost wages, medical expenses, insurance costs, and indirect costs. The number of persons injured in **industrial place accidents** in a typical year is 7,128,000, or 3 per 100 persons per year.[2] In the workplace, there is one accidental death approximately every 51 minutes and one injury every 19 seconds.[3]

Why do accidents happen? This question has concerned safety and health decision makers for decades, because in order to prevent accidents we must know why they happen. Over the years, several theories of accident causation have evolved that attempt to explain why accidents occur. Models based on these theories are used to predict and prevent accidents.

The most widely known theories of accident causation are the domino theory, the human factors theory, the accident/incident theory, the epidemiological theory, the systems theory, the combination theory, and the behavioral theory. This chapter provides

practicing and prospective safety professionals with the information they need to understand fully and apply these theories.

DOMINO THEORY OF ACCIDENT CAUSATION

An early pioneer of accident prevention and industrial safety was Herbert W. Heinrich, an official with the Travelers Insurance Company. In the late 1920s, after studying the reports of 75,000 industrial accidents, Heinrich concluded that

- 88 percent of industrial accidents are caused by unsafe acts committed by fellow workers.
- 10 percent of industrial accidents are caused by unsafe conditions.
- 2 percent of industrial accidents are unavoidable.[4]

Heinrich's study laid the foundation for his *Axioms of Industrial Safety* and his theory of accident causation, which came to be known as the **domino theory**. **So much of Heinrich's theory has been discounted by more contemporary research that it is now considered outdated.** However, because some of today's more widely accepted theories can be traced back to Heinrich's theory, students of industrial safety should be familiar with his work.

Heinrich's Axioms of Industrial Safety

Heinrich summarized what he thought health and safety decision makers should know about industrial accidents in 10 statements he called **Axioms of Industrial Safety**. These axioms can be paraphrased as follows:

1. Injuries result from a completed series of factors, one of which is the accident itself.
2. An accident can occur only as the result of an unsafe act by a person and/or a physical or mechanical hazard.
3. Most accidents are the result of unsafe behavior by people.
4. An unsafe act by a person or an unsafe condition does not always immediately result in an accident/injury.
5. The reasons why people commit unsafe acts can serve as helpful guides in selecting corrective actions.
6. The severity of an accident is largely fortuitous, and the accident that caused it is largely preventable.
7. The best accident prevention techniques are analogous with the best quality and productivity techniques.
8. Management should assume responsibility for safety because it is in the best position to get results.
9. The supervisor is the key person in the prevention of industrial accidents.
10. In addition to the direct costs of an accident (e.g., compensation, liability claims, medical costs, and hospital expenses), there are also hidden or indirect costs.[5]

According to Heinrich, these axioms encompass the fundamental body of knowledge that must be understood by decision makers interested in preventing accidents. Any accident prevention program that takes all 10 axioms into account is more likely to be effective than a program that leaves out one or more axioms.

Heinrich's Domino Theory

Perhaps you have stood up a row of dominoes, tipped the first one over, and watched as each successive domino topples the one next to it. This is how Heinrich's theory of accident causation works. According to Heinrich, there are five factors in the sequence of events leading up to an accident. These factors can be summarized as follows:

1. **Ancestry and social environment.** Negative character traits that may lead people to behave in an unsafe manner can be inherited (**ancestry**) or acquired as a result of the **social environment** (e.g., alcoholism).
2. **Fault of person.** Negative character traits, whether inherited or acquired, are why people behave in an unsafe manner and why hazardous conditions exist.
3. **Unsafe act/mechanical or physical hazard. Unsafe acts** committed by people and **mechanical** or **physical hazards** are the direct causes of accidents.
4. **Accident.** Typically, accidents that result in injury are caused by falling or being hit by moving objects.
5. **Injury.** Typical injuries resulting from accidents include lacerations and fractures.[6]

Heinrich's theory has two central points: (1) injuries are caused by the action of **preceding factors** and (2) removal of the **central factor** (unsafe act/**hazardous condition**) negates the action of the preceding factors and, in so doing, prevents accidents and injuries.

Heinrich's Theory and Corrective Action

The three "E's" of safety—Engineering, Education, and Enforcement—(Chapter 1) work well in taking corrective action in conjunction with Heinrich's theory. The engineering component recommends that hazards be controlled through better product design or process improvements. The education component recommends training workers on all aspects of safe work practices and management on their role in providing a safe working environment. The enforcement component recommends that safety professionals, managers, supervisors, and fellow workers act immediately when someone is observed ignoring safe work practices. Safety rules and procedures have no value unless they are followed, and they will not be followed unless they are enforced.

Domino Theory in Practice

Construction Products Company (CPC) is a distributor of lumber, pipe, and concrete products. Its customers are typically small building contractors. CPC's facility consists of an office in which orders are placed and several large warehouses. Contractors place their orders in the office. They then drive their trucks through the appropriate warehouses to be loaded by CPC personnel.

Because the contractors are small operators, most of their orders are also relatively small and can be loaded by hand. Warehouse personnel go to the appropriate bins, pull out the material needed to fill their orders, and load the materials on customers' trucks. Even though most orders are small enough to be loaded by hand, many of the materials purchased are bulky and cumbersome to handle. Because of this, CPC's loaders are required to wear such personal protection gear as hard hats, padded gloves, steel-toed boots, and lower-back-support belts.

For years, CPC's management team had noticed an increase in minor injuries to warehouse personnel during the summer months. Typically, these injuries consisted of nothing worse than minor cuts, scrapes, and bruises. However, this past summer had been different. Two warehouse workers had sustained serious back injuries. These injuries have been costly to CPC both financially and in terms of employee morale.

An investigation of these accidents quickly identified a series of events and a central causal behavior that set up a *domino effect* that, in turn, resulted in the injuries. The investigation revealed that CPC's warehouses became so hot during the summer months that personal protection gear was uncomfortable. As a result, warehouse personnel simply discarded it. Failure to use appropriate personal protection gear in the summer months had always led to an increase in injuries. However, because the injuries were minor in nature, management had never paid much attention to the situation. It was probably inevitable that more serious injuries would occur eventually.

To prevent a recurrence of the summer-injury epidemic, CPC's management team decided to remove the causal factor—failure of warehouse personnel to use their personal protection gear during the summer months. To facilitate the removal of this factor, CPC's management team formed a committee consisting of one executive manager, one warehouse supervisor, and three warehouse employees.

The committee made the following recommendations: (1) provide all warehouse personnel with training on the importance and proper use of personal protection gear; (2) require warehouse supervisors to monitor the use of personal protection gear more closely; (3) establish a company policy that contains specific and progressive disciplinary measures for failure to use required personal protection gear; and (4) implement several heat reduction measures to make warehouses cooler during the summer months.

CPC's management team adopted all the committee's recommendations. In doing so, it removed the central causal factor that had historically led to an increase in injuries during the summer months.

HUMAN FACTORS THEORY OF ACCIDENT CAUSATION

The **human factors theory** of accident causation attributes accidents to a chain of events ultimately caused by **human error**. It consists of the following three broad factors that lead to human error: overload, inappropriate response, and inappropriate activities (see Figure 3–1). These factors are explained in the following paragraphs.

FIGURE 3–1 Factors that cause human errors.

Human Error Factors
• Overload
• Inappropriate activities
• Inappropriate responses

Overload

Overload amounts to an imbalance between a person's capacity at any given time and the load that person is carrying in a given state. A person's capacity is the product of such factors as his or her natural ability, training, state of mind, fatigue, stress, and physical condition. The load that a person is carrying consists of tasks for which he or she is responsible and added burdens resulting from **environmental factors** (noise, distractions, and so on), **internal factors** (personal problems, emotional stress, and worry), and **situational factors** (level of risk, unclear instructions, and so on). The state in which a person is acting is the product of his or her motivational and arousal levels.

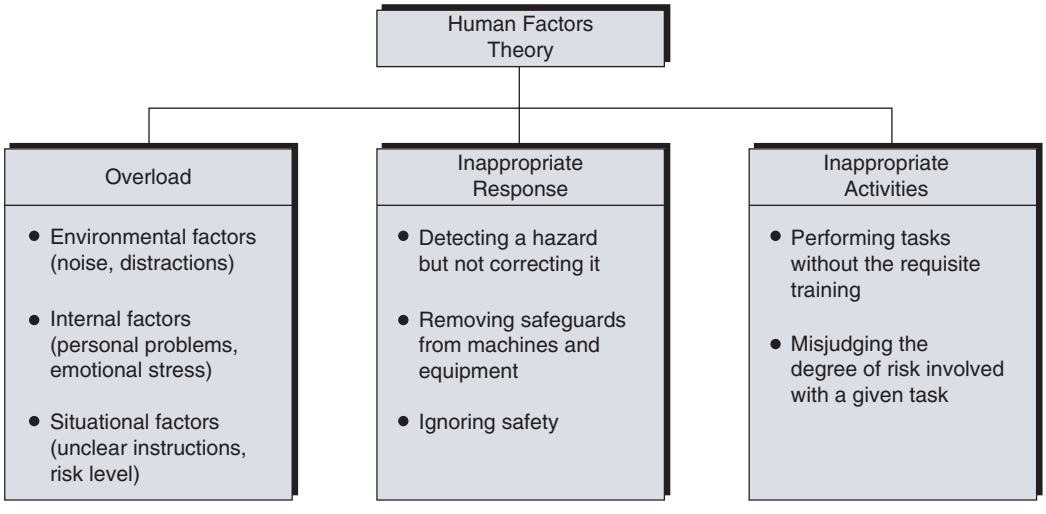
Inappropriate Response and Incompatibility

How a person responds in a given situation can cause or prevent an accident. If a person detects a hazardous condition but does nothing to correct it, he or she has responded inappropriately. If a person removes a safeguard from a machine in an effort to increase output, he or she has responded inappropriately. If a person disregards an established safety procedure, he or she has responded inappropriately. Such responses can lead to accidents. In addition to **inappropriate responses**, this component includes workstation incompatibility. The incompatibility of a person's workstation with regard to size, force, reach, feel, and similar factors can lead to accidents and injuries.

Inappropriate Activities

Human error can be the result of **inappropriate activities**. An example of an inappropriate activity is a person who undertakes a task that he or she doesn't know how to do. Another example is a person who misjudges the degree of risk involved in a given task and proceeds based on that misjudgment. Such inappropriate activities can lead to accidents and injuries. Figure 3–2 summarizes the various components of the human factors theory.[7]

FIGURE 3–2 Human factors theory.



Human Factors Theory in Practice

Kitchenware Manufacturing Incorporated (KMI) produces aluminum kitchenware for commercial settings. After 10 years of steady, respectable growth in the U.S. market, KMI suddenly saw its sales triple in less than six months. This rapid growth was the result of KMI's successful entry into European and Asian markets.

The growth in sales, although welcomed by both management and employees, quickly overloaded and, before long, overwhelmed the company's production facility. KMI responded by adding a second shift of production personnel and approving unlimited overtime for highly skilled personnel. Shortly after the upturn in production, KMI began to experience a disturbing increase in accidents and injuries. During his accident investigations, KMI's safety manager noticed that human error figured prominently in the accidents. He grouped all the human errors identified into three categories: (1) overload, (2) inappropriate response, and (3) inappropriate activities.

In the category of *overload*, he found that the rush to fill orders was pushing production personnel beyond their personal limits in some cases, and beyond their capabilities in others. Stress, insufficient training of new employees, and fatigue all contributed to the overload. In the category of *inappropriate response*, the safety manager determined that many of KMI's production personnel had removed safeguards from their machines in an attempt to speed up production. All the machines involved in accidents had had safeguards removed.

In the category of *inappropriate activities*, the safety manager found that new employees were being assigned duties for which they weren't yet fully trained. As a result, they often misjudged the amount of risk associated with their work tasks.

With enough accident investigations completed to identify a pattern of human error, the safety manager prepared a presentation containing a set of recommendations for corrective measures for KMI's executive management team. His recommendations were designed to prevent human-error-oriented accidents without slowing production.

ACCIDENT/INCIDENT THEORY OF ACCIDENT CAUSATION

The **accident/incident theory** is an extension of the human factors theory. It was developed by Dan Petersen and is sometimes referred to as the Petersen accident/incident theory.[8] Petersen introduced such new elements as **ergonomic traps**, the decision to err, and systems failures, while retaining much of the human factors theory. A model based on his theory is shown in Figure 3–3.

In this model, overload, ergonomic traps, or a decision to err leads to human error. The decision to err may be conscious and based on logic, or it may be unconscious. A variety of pressures such as deadlines, peer pressure, and budget factors can lead to **unsafe behavior**. Another factor that can influence such a decision is the "it won't happen to me" syndrome.

The systems failure component is an important contribution of Petersen's theory. First, it shows the potential for a **causal relationship** between management decisions or management behavior and safety. Second, it establishes management's role in accident prevention as well as the broader concepts of safety and health in the workplace.