SAFETY PROFESSIONAL'S REFERENCE AND STUDY GUIDE

FOURTH EDITION



W. David Yates

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Safety Professional's Reference and Study Guide

For safety professionals navigating the complexities of safety practices daily, the search for a single-source guide covering diverse topics has been an ongoing quest. Now, in its fourth edition, *Safety Professional's Reference and Study Guide* has expanded its scope, incorporating crucial new chapters on legal aspects of the safety profession, recordkeeping, sustainability principles, and more, catering to the evolving needs of the Environmental Health and Safety (EHS) community.

This title is every safety professional's indispensable, market-leading resource, empowering the reader to tackle challenges with confidence and expertise. Exploring core aspects of occupational safety, this book offers a wealth of knowledge, each chapter offering practical insights and actionable advice. The title goes beyond conventional boundaries, addressing emerging topics such as electrical safety, risk assessment, and sustainability principles in brand-new chapters.

A go-to guide for any practicing safety professional seeking a quick desk reference, a student supplementing their textbooks, or a candidate preparing for certification exams including ASP, CSP, OHST, or CHST, it equips readers with the knowledge and skills needed to navigate the evolving landscape of occupational safety focusing on real-world applications and exam readiness.



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Fourth Edition

W. David Yates



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Dedication

I remain enormously grateful to my wonderful and supportive wife, Sharon, who has always been there. Her wisdom and guidance cannot be underestimated. I would also like to acknowledge our children, Joseph, Jason, Katie, Cody, and Jesse, as well as our grandchildren, Jordan Nicole, Jonathon Elisha, Jacob Michael, Bailey Addison, Mason Tanner, Madison Olivia, Jagger Gray, Malaya Brook, Hattie Grace, and Braeden Gage, to all of whom I dedicate this book.



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Preface

During my professional career, I have had the opportunity to read and utilize numerous technical resources. As a practicing safety professional in comprehensive practice, I am yet to find a single-source reference that includes most of the information that I encounter daily. That is not to say that there are not useful references available. However, it has been my experience that maintaining a library suitable for comprehensive practice becomes very costly and requires a wide variety of topics to get the information that is needed. Most of the useful references available focus primarily on the practicing industrial hygienist.

It is for this reason that I set out to publish the first edition of the book. It was intended to serve several purposes as outlined below:

- To function as a "quick desk reference" for the experienced, practicing safety professional in comprehensive or specialized practice.
- To be utilized by university students at all levels as a useful reference tool to supplement more in-depth textbooks.
- To serve as a primary study resource for those individuals preparing to take the Associate Safety Professional (ASP), Certified Safety Professional (CSP), Occupational Health and Safety Technologist (OHST), and the Construction Health and Safety Technologist (CHST) examinations.

The first, second, and third editions had a very positive response from my fellow safety professionals, as well as students and prospective ASP/CSP candidates. In this edition, I have added new chapters on the legal aspects of the safety professional (beyond the basic regulations, but a review of laws and the court systems), Recordkeeping and Reporting Occupational Injuries and Illnesses, Sustainability and Sustainability Principles, Prevention through Design, Management of Change (MoC), and Emergency Preparedness. In addition to the new chapters, this book will serve as a primary study guide for the examinations listed above. It includes such topics as Basic Requirements of the Certification Process, Regulations, OSHA Record Keeping, Particulates and Gases, Toxicology, Industrial Hygiene, Ventilation, Noise, Biological Hazards, Thermal Stressors, Personal Protective Equipment, Math Review, Statistics for the Safety Professional, Fire Protection and Prevention,

Mechanics, Hydrostatics and Hydraulics, Electrical Safety, Engineering Economy, Training and Worker's Compensation Issues. It is my belief that the reader of this book will determine it to be an "invaluable" resource at any level of their professional safety career.

Author Biography

W. David Yates was born in Morton, Mississippi, and lived most of his childhood in Crystal Springs, Mississippi. He has earned a B.S. degree in Health Care Services from Southern Illinois University, Carbondale, Illinois; an M.S. degree in Hazardous Materials Management from Jackson State University, Jackson, Mississippi; a PhD in Environmental Science from Jackson State University, Jackson, Mississippi; and J.D. (General Law) from Birmingham School of Law. Dr Yates served ten years in the United States Navy as a Preventive Medicine Technician. He retired from the United States Army Reserves as an Environmental Science and Preventive Medicine Officer, having attained the rank of Colonel. In his civilian career, Dr Yates has operated his own professional consulting firm, served as the Safety and Mission Assurance Manager for Stennis Space Center, Mississippi; the Corporate Safety Director for Bodine Services of the Midwest, Decatur, Illinois; and several Safety and Security Manager positions in mining and manufacturing.

Currently he is the President and Owner of Southern Safety Solutions, LLC, a safety consulting firm located in Clanton, Alabama. He is a Certified Safety Professional (CSP) with the Board of Certified Safety Professionals. Dr Yates is also a full-time Faculty for Columbia Southern University in Environmental Management with an extensive knowledge and experience in hazardous materials management, safety programs management, indoor air quality, ventilation, noise, and industrial hygiene sampling and analysis.

Acknowledgements

My sincere appreciation for the assistance provided by Mr. Johnny McNeel and Greg Kelly for their assistance in creating the figures and photographs provided in Chapter 30—Materials Handling. I could not have completed this chapter without their help.

I would also like to express my gratitude to D.J. Schmutz of MSHA Safety Services for his clarifications on many regulatory details.

1

The Safety Profession and Preparing for the ASP/CSP Exam

The safety profession has a long and distinguished history tracing back to Hammurabi (ca. 1728–1686 BC), who was the sixth king of Babylon. Hammurabi is best known for his codification of laws, which included some, if not the first, set of workers compensation laws known. The safety profession has greatly changed since the days of Hammurabi. On December 29, 1970, Public Law 91-596 (The Williams–Steiger Occupational Safety and Health Act of 1970) was signed into law. This legislation focused on controlling workplace hazards and ensuring safe and healthful working conditions for working men and women by authorizing enforcement of the standards developed under the Act; by assisting and encouraging the states in their efforts to ensure safe and healthful working conditions; by providing for research, information, education, and training in the field of occupational safety and health; and for other purposes. Under the Act, the Occupational Safety and Health Administration was created within the Department of Labor. The passage of this legislation highlighted the need for educated and knowledgeable professionals in the area of safety and health. Over the past 39 years, the safety profession has matured, as evidenced by universities offering undergraduate and advanced degrees in safety and health, the placement of safety professionals at the highest levels of management, and the certification of safety professionals. Today's safety profession requires a broad range of knowledge, including biology, chemistry, mathematics, business, and management. Your decision to become a candidate for the Certified Safety Professional (CSP) designation is an important step in your professional career. This book is written to assist you in achieving that ultimate designation as a safety professional.

Board of Certified Safety Professionals

The Board of Certified Safety Professionals (BCSP) was organized in 1969 as a peer certification board. Its purpose is to certify practitioners in the safety profession. The specific functions of the Board are to

- Evaluate the academic and professional experience qualifications of safety professionals

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- Administer examinations
- Issue certifications to those professionals who meet the Board's criteria and successfully pass the required examinations

In 1968, the American Society of Safety Engineers studied the issue of certification for safety professionals and recommended the formation of a professional certification program. This recommendation led to the establishment of BCSP in July 1969. The BCSP governing Board consists of 13 directors who represent the breadth and depth of safety, health, and environmental practice, as well as the public. Six of the directors are nominated to a pool by professional membership organizations affiliated with BCSP. The professional membership organizations currently affiliated with BCSP are the following:

- American Industrial Hygiene Association
- American Society of Safety Engineers
- Institute of Industrial Engineers
- National Fire Protection Association
- National Safety Council
- Society of Fire Protection Engineers
- System Safety Society

BCSP has issued credentials to more than 100,000 people, and more than 67,000 currently hold credentials. There are currently 25,674 Certified Safety Professionals, 7,445 Associate Safety Professionals, 7,449 Graduate Safety Professionals, 1,983 Occupational Health and Safety Technologists, 11,323 Construction Health and Safety Technologists, and 2,702 Certified Instructional Trainers.

The CSP credential meets or exceeds the highest national and international accreditation and personnel certification standards for certification bodies. International Accreditation is ISO/IEC 17024 and National Accreditation is the National Commission for Certifying Agencies.

Definitions

Note: The information throughout this chapter is derived from "A Complete Guide to Safety Certification," April 2024. This information is derived from copyrighted materials that are owned and copyrighted by the Board of Certified Safety Professionals.

BCSP's certifications are accredited by the American National Standards Institute (ANSI) Accreditation Board (ANAB), an independent third-party organization that evaluates certification program and organization requirements on a regular basis.

A *safety professional* is one who applies the expertise gained from a study of safety science, principles, practices, and other subjects, and from professional safety experience, to create or develop procedures, processes, standards, specifications, and systems to achieve optimal control or reduction of the hazards and exposures that may harm people, property, or the environment.

Professional safety experience, as interpreted by BCSP, must be the primary function of a position and account for at least 50% of the position's responsibilities. Professional safety experience involves analysis, synthesis, investigation, evaluation, research, planning, design, administration, and consultation to the satisfaction of peers, employers, and clients in the prevention of harm to people, property, and the environment. Professional safety experience differs from nonprofessional experience in the degree of responsible charge and the ability to defend analytical approaches and recommendations for engineering or administrative controls.

A *Certified Safety Professional* or *CSP* is a safety professional who has met and continues to meet all the requirements established by BCSP and is authorized by BCSP to use the Certified Safety Professional title and the CSP credential. Certificants who hold the CSP mostly work in private industry, which could include being a government contractor. A CSP who works in the government sector may work in the military, federal, state, or local agencies. Safety at this level is present in virtually every industry, including petroleum exploration, production and refining, manufacturing, construction, healthcare, and insurance. A CSP's professional time is spent on safety management systems, occupational health and ergonomics, emergency response and preparedness, fire prevention and protection, and security responsibilities. A CSP may also have environmental management system responsibilities, including managing safety, health, and environmental programs that can cover up to 1,000 or more employees.

An *Associate Safety Professional* or *ASP* is now a full certification offered by the BCSP. It was previously only a temporary credential before becoming a CSP awarded by BCSP. This designation describes an individual who has met the academic requirements for the ASP certification and has passed the Safety Fundamentals Examination, the first of two examinations leading to the CSP credential. Associate Safety Professionals (ASP) are persons who perform at least 50% of professional-level safety duties including making worksite assessments to determine risks, potential hazards, and controls, evaluating risks and hazard control measures; investigating incidents; maintaining and evaluating incident and loss records; and preparing emergency response plans. Other duties could include hazard recognition, fire protection, regulatory compliance, health hazard control, ergonomics, hazardous materials management, environmental protection, training, accident and

incident investigations, advising management, record keeping, emergency response, managing safety programs, product safety, and/or security.

A *Graduate Safety Practitioner* or *GSP* is a temporary designation awarded by BCSP. This designation describes an individual who has graduated from an independently accredited academic program meeting BCSP's standards. GSPs must sit for and pass the Certified Safety Professional (CSP) examination within 6 years of the date the GSP is awarded.

Minimum Qualifications to Sit for the ASP Examination

As already mentioned above, the ASP is now a fully recognized stand-alone certification/credential offered by the BCSP. The minimum qualifications to sit for the ASP examination include academic requirements, professional safety experience requirements, successfully passing the ASP (or obtaining a waiver), and ASP examinations. BCSP requires a minimum of a bachelor's degree in any field or an associate degree in safety, health, or the environment, 1 year of professional safety experience, passing the ASP examination and retaining the certification.

Academic Requirements

All individuals applying for the ASP must have a bachelor's degree or higher in any field from an accredited institution or an associate degree in safety, health, or the environment. The associate degree must include at least four (4) courses with a minimum of 12 semester hours/18 quarter hours of study in the safety, health, or environmental domains covered in the ASP and CSP examination blueprints.

There is no waiver of the academic requirement, and proof of a minimum qualifying degree must be provided. For US degrees, BCSP requires the school to hold institutional accreditation recognized by the Council for Higher Education Accreditation (CHEA) (chea.org) and/or the US Department of Education (ed.gov).

Unaccredited degrees are a growing concern, and some states have laws making it illegal to use unaccredited degrees. Applicants and certificants cannot use unaccredited degrees, and their use is a violation of the *BCSP Code of Ethics*.

Professional Safety Experience

The candidate must have a minimum of one (1) year of safety experience of professional experience to sit for the ASP exam. Professional safety experience must meet the following criteria to qualify:

- Professional safety must be the primary function of the position. Collateral duties in safety are not counted.
- The position's primary responsibility must be the prevention of harm to people, property, or the environment, rather than responding to harmful events.
- Professional safety functions must be at least 50% of the position duties. BCSP defines full-time as at least 35 h per week. Part-time safety experience is allowed if the applicant has the equivalent of at least 900 h of professional safety work during any year (75 h per month or 18 h per week) for which experience credit is sought.
- The position must be at a professional level. This is determined by evaluating the degree of professional responsibility by which there is a reliance of employees, employers, or clients on the person's ability to identify, evaluate, and control hazards through engineering and/or administrative approaches.
- The position must have a breadth of professional safety duties. This is determined by evaluating the variety of hazards about which the candidate must advise, and the range of skills involved in recognizing, evaluating, and controlling hazards.

Minimum Qualifications to Sit for the CSP Examination

The minimum qualifications to sit for the CSP examination include academic requirements, professional safety experience requirements, successfully passing the ASP (or obtaining a waiver), and CSP examinations. BCSP requires a minimum of a bachelor's degree, 4 years of safety experience, passing the CSP Examination and retaining the certification. To qualify for the CSP examination, a candidate must have already attained one of the following BCSP Qualified Credentials:

- Associate Safety Professional (ASP)*
- Graduate Safety Practitioner (GSP)
- Transitional Safety Practitioner (TSP)*
- Certified Industrial Hygienist® (CIH®)
- Chartered Member of the Institution of Occupational Safety and Health (CMIOSH)*
- Canadian Registered Safety Professional (CRSP)*
- CP-12 Professional Certificate in Safety and Occupational Health, US Army Combat Readiness Center (ACRC)*

- Certified Safety Engineer (CSE), as administered by the State Administration of Work Safety (SAWS), People's Republic of China (PRC)*
- Master in Occupational Safety and Health, International Training Centre of the International Labour Organization (ITC-ILO)*
- National Examination Board in Occupational Safety and Health (NEBOSH) National or International Diploma in Occupational Health and Safety
- Professional Member of the Singapore Institution of Safety Officers (SISO)*
- Diploma/Certificate in Industrial Safety, as issued by the State Government Departments, Boards of Technical Education, Government of India*

*Note that all education requirements must be met when pursuing the CSP.

Academic Requirements

All individuals applying for the ASP must have a bachelor's degree or higher in any field from an accredited institution or an associate degree in safety, health, or the environment. The associate degree must include at least four courses with a minimum of 12 semester hours/18 quarter hours of study in the safety, health, or environmental domains covered in the ASP and CSP examination blueprints.

There is no waiver of the academic requirement, and proof of a minimum qualifying degree must be provided. For US degrees, BCSP requires the school to hold institutional accreditation recognized by the Council for Higher Education Accreditation (CHEA) (chea.org) and/or the US Department of Education (ed.gov).

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Professional Safety Experience Requirements

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- Professional safety must be the primary function of the position. Collateral duties in safety are not counted.
- The position's primary responsibility must be the prevention of harm to people, property, or the environment, rather than responding to harmful events.

- Professional safety functions must be at least 50% of the position's duties. BCSP defines full-time as at least 35 hours per week. Part-time safety experience is allowed if the applicant has the equivalent of at least 900 hours of professional safety work during any year (75 hours per month or 18 hours per week) for which experience credit is sought.
- The position must be at a professional level. This is determined by evaluating the degree of professional charge by which there is a reliance of employees, employers, or clients on the person's ability to identify, evaluate, and control hazards through engineering and/or administrative approaches.
- The position must have a breadth of professional safety duties. This is determined by evaluating the variety of hazards about which the candidate must advise, and the range of skills involved in recognizing, evaluating, and controlling hazards.

ASP/CSP Process

The process for both the ASP and CSP Certifications is very similar. Specific details can be found by visiting the Board of Certified Safety Professionals website, which is located at https://online.fliphtml5.com/pbcyp/ijfs/. In general, however, the process is as follows:

- Pick a certification
- Determine eligibility
- Submit the appropriate application, along with the fees
- Purchase the examination
- Schedule the examination
- Sit for the examination
- Maintain certification

Examination Blueprint

In order to prepare for an examination, one must have a plan. In order to have a plan, the candidate will need to know the materials that are to be tested. The examination blueprints listed below indicate the main topics to be tested for each certification.

Associate Safety Professional Examination Blueprint

The details of this blueprint can be found by visiting the following website: https://www.bcsp.org/wp-content/uploads/2021/12/ASP-Blueprint.pdf

Domain #1—Advanced Sciences and Math (11.55%)

Topic 1: General chemistry concepts
Topic 2: Electrical principles
Topic 3: Principles of radioactivity
Topic 4: Storage capacity calculations
Topic 4: Rigging and load calculations
Topic 6: Ventilation and system design
Topic 7: Noise hazards
Topic 8: Climate and environmental conditions
Topic 9: Fall protection calculations
Topic 10: General physics
Topic 11: Financial principles
Topic 12: Descriptive statistics
Topic 13: Lagging indicators
Topic 14: Leading indicators

Domain #2—Safety Management Systems (17.22%)

Topic 1: Hierarchy of hazard controls
Topic 2: Risk transfer
Topic 3: Management of change
Topic 4: Hazard and risk analysis methods
Topic 5: Process safety management
Topic 6: Fleet safety principles
Topic 7: Hazard communication and globally harmonized system
Topic 8: Control of hazardous energy
Topic 9: Excavation, trenching, and shoring
Topic 10: Confined space
Topic 11: Physical security
Topic 12: Fall protection
Topic 13: Machine guarding
Topic 14: Powered industrial vehicles
Topic 15: Scaffolding

Domain #3—Ergonomics (9%)

Topic 1: Fitness for duty
Topic 2: Stressors

Topic 3: Risk factors
Topic 4: Work design
Topic 5: Material handling
Topic 6: Work practice controls

Domain #4—Fire Prevention and Protection (10.66%)

Topic 1: Chemical
Topic 2: Electrical
Topic 3: Hot work
Topic 4: Combustible dust
Topic 5: Fire science
Topic 6: Detection systems
Topic 7: Suppression systems, fire extinguishers, and sprinkler types
Topic 8: Segregation and separation
Topic 9: Housekeeping

D #5—Emergency Response Management (9.57%)

Topic 1: Emergency crisis, disaster response planning
Topic 2: Workplace violence

Domain #6—Industrial Hygiene and Occupational Health (12.59%)

Topic 1: Sources of biological hazards
Topic 2: Protocol for bloodborne pathogen control
Topic 3: Mutagens, teratogens, and carcinogens
Topic 4: Chemical hazards
Topic 5: Exposure limits
Topic 6: Routes of entry
Topic 7: Acute and chronic exposures
Topic 8: Noise
Topic 9: Radiation
Topic 10: Heat and cold stress

Domain #7—Environmental Management (15%)

Topic 1: Environmental hazards
Topic 2: Water
Topic 3: Air
Topic 4: Land and conservation
Topic 5: Hierarchy of conservation
Topic 6: Environmental management system standards
Topic 7: Waste removal, treatment, and disposal

Domain #8—Training, Education, and Communication (12.35%)

Topic 1: Adult learning theory and techniques
Topic 2: Presentation tools
Topic 3: Safety culture/climate
Topic 4: Data collection, needs analysis, gap analysis, and feedback
Topic 5: Assessing competency

Domain #9—Law and Ethics (8.38%)

Topic 1: Legal liability
Topic 2: Ethical behavior
Topic 3: Protection of worker privacy

Certified Safety Professional (CSP) Examination Blueprint

The details of this blueprint can be found by visiting the following website: https://www.bcsp.org/wp-content/uploads/2021/12/CSP-Blueprint.pdf.

Domain #1—Advanced Sciences and Math (9.95%)

Topic 1: Core concepts in anatomy and physiology
Topic 2: Core concepts in chemistry
Topic 3: Core concepts in physics
Topic 4: Core concepts in mathematics
Topic 5: Statistics for interpreting data
Topic 6: Core research methodology
Topic 7: Microbiology

Domain #2—Management Systems (13.34%)

Topic 1: Benchmarks and performance of standards
Topic 2: How to measure, analyze, and improve organizational culture
Topic 3: Incident investigation techniques and analysis
Topic 4: Management of change techniques
Topic 5: System safety analysis techniques
Topic 6: Elements of business continuity and contingency plans
Topic 7: Leading and lagging safety and health indicators
Topic 8: EHS management and audit systems
Topic 9: Applicable requirements for plans, systems, and policies
Topic 10: Document retention or management
Topic 11: Budgeting, finance, and economic analysis techniques
Topic 12: Management leadership techniques
Topic 13: Project management concepts

Domain #3—Risk Management (14.49%)

Topic 1: Hazard identification and analysis methods (e.g., job safety analysis, hazard analysis, human performance analysis, and audit and causal analysis)
Topic 2: Risk analysis
Topic 3: Risk evaluation (decision making)
Topic 4: The risk management process
Topic 5: The costs and benefits of risk assessment process
Topic 6: Insurance/risk transfer principles

Domain #4—Advanced Application of Key Safety Concepts (14.69%)

Topic 1: Principles of safety through design and inherently safer designs (e.g., designing out hazards during design phase, avoidance, elimination, and substitution)
Topic 2: Engineering controls (e.g., ventilation, guarding, isolation, and active vs. passive)
Topic 3: Administrative controls (e.g., job rotation, training, procedures, and safety policies and practices)
Topic 4: Personal protective equipment
Topic 5: Chemical process safety management (e.g., pressure relief systems, chemical compatibility, management of change, materials of construction, and process flow diagrams)
Topic 6: Redundancy systems (e.g., energy isolation and ventilation)
Topic 7: Common workplace hazards (e.g., electrical, falls, same level falls, confined spaces, lockout/tagout, working around water, caught in, struck by, excavation, welding, hot work, cold and heat stress, combustibles, laser, and others)
Topic 8: Facility life safety features (e.g., public space safety, floor loading, and occupancy loads)
Topic 9: Fleet safety principles (e.g., driver and equipment safety, maintenance, surveillance equipment, GPS monitoring, telematics, hybrid vehicles, fuel systems, driving under the influence, and fatigue)
Topic 10: Transportation safety principles (e.g., air, rail, and marine)
Topic 11: Materials handling (e.g., forklifts, cranes, hand trucks, person lifts, hoists, rigging, manual, and drones)
Topic 12: Foreign material exclusion (FME) and foreign object damage (FOD)
Topic 13: Hazardous materials management (e.g., GHS labels, storage and handling, policy, and security)
Topic 14: Multi-employee worksite issues (e.g., contractors and temporary or seasonal employees)
Topic 15: Sources of information on hazards and risk management options (e.g., subject matter experts, relevant best practices, published literature, and SDS)

Topic 16: The safety design criteria for workplace facilities, machines, and practices (e.g., UL, NFPA, NIOSH, FM, and ISO)
Topic 17: Tools, machines, practices, and equipment safety (e.g., hand tools, ladders, grinders, hydraulics, and robotics)
Topic 18: Workplace hazards (e.g., nanoparticles, combustible dust, heat systems, high pressure, radiation, silica dust, powder and spray applications, blasting, and molten metals)
Topic 19: Human performance

Domain #5—Emergency Preparedness, Fire Prevention, and Security (10.59%)

Topic 1: Emergency/crisis/disaster response planning/business continuity (e.g., nuclear incidents, natural disasters, terrorist attacks, chemical spills, fires, active violent attacks, and public utilities)
Topic 2: Fire prevention, protection, and suppression systems
Topic 3: The transportation and security of hazardous materials
Topic 4: Workplace violence and prevention techniques (violence on employees)

Domain #6—Occupational Health and Ergonomics (12.05%)

Topic 1: Advanced toxicology principles (e.g., symptoms of an exposure, LD_{50}, mutagens, teratogens, and ototoxins)
Topic 2: Carcinogens
Topic 3: Ergonomics and human factor principles (e.g., visual acuity, body mechanics, lifting, vibration, anthropometrics, and fatigue management)
Topic 4: How to recognize occupational exposures (e.g., hazardous chemicals, radiation, noise, biological agents, heat/cold, infectious diseases, nanoparticles, and indoor air quality)
Topic 5: How to evaluate occupational exposures (e.g., hazardous chemicals, radiation, noise, biological agents, heat/cold, infectious diseases, ventilation, nanoparticles, and indoor air quality), including techniques for measurement, sampling, and analysis
Topic 6: How to control occupational exposures (e.g., hazardous chemicals, radiation, noise, biological agents, heat/cold, ventilation, nanoparticles, infectious diseases, and indoor air quality)
Topic 7: Employee substance abuse
Topic 8: The fundamentals of epidemiology
Topic 9: Occupational exposure limits (e.g., hazardous chemicals, radiation, noise, biological agents, and heat)

Domain #7—Environmental Management Systems (7.38%)

Topic 1: Environmental protection and pollution prevention methods (e.g., air, water, soil, containment, soil vapor intrusion, and waste streams)

Topic 2: How released hazardous materials migrate/interact through the air, surface water, soil, and water table
Topic 3: Sustainability principles
Topic 4: Wastewater treatment plants, onsite wastewater treatment plants, and public water systems
Topic 5: Registration, evaluation, authorization, and restriction of chemicals (REACH) and restriction of hazardous substances (RoHS)

Domain #8—Training and Education (10.18%)

Topic 1: Education and training methods and techniques (e.g., classroom, online, computer-based, AI, and on-the-job training)
Topic 2: Training, qualification, and competency requirements
Topic 3: Methods for determining the effectiveness of training programs (e.g., determining if trainees are applying training on the job)
Topic 4: Effective presentation techniques

Domain #9—Law and Ethics (7.33%)

Topic 1: Legal issues (e.g., tort, negligence, civil, criminal, contracts, and disability terminology)
Topic 2: Protection of confidential information (e.g., privacy, trade secrets, personally identifiable information, and General Data Protection Regulation [GDPR])
Topic 3: Standards development processes
Topic 4: The ethics related to conducting professional practice (e.g., audits, record keeping, sampling, and standard writing)
Topic 5: The relationship between labor and management
Topic 6: BCSP code of ethics
Topic 7: Workers' compensation (e.g., injured worker's compensation)

Preparing for the ASP/CSP Examinations

Now that you understand the process of qualifying for the examination and the information that you will be tested on, you will need to develop a plan of action to prepare to take the examinations. The methods and techniques used for preparing for the examinations are an individual's decision. The methods listed in this chapter have been developed over the years and have been determined to be highly successful. There are no shortcuts to preparing for these examinations. Preparation for this examination started in elementary and high school, by taking the required courses in math, science, economics, and business. With this being said, this chapter will guide you through some time-proven methods and techniques that will assist you in successfully passing the examinations and obtaining the professional designations.

Knowing Your Strengths and Weaknesses

One of your first steps in preparing for the ASP/CSP examinations is to determine where your strengths and weaknesses are. This can be achieved in a number of ways. One way is to do a self-evaluation, by rating yourself on how well you know each subject area listed in the domains. Simply look at the domains and individual topics or tasks and rate yourself on how well you are familiar with the topic or task. A second method of determining how well you know the topic is to take a self-assessment examination. These self-assessment examinations can be purchased from BCSP for approximately $95.00 each. They are useful in determining your initial status and for studying for the examination. A rating form to assist you in rating yourself is available on the BCSP website by downloading the examination guides. There is no cost for this document.

Developing an Examination Preparation Plan

Based on the results of your self-evaluation, the next step is to develop a plan to prepare for the examination. There is no set period to prepare for the examination. The time required to prepare is strictly a personal decision. Personal experience has shown that the average person with a solid background in mathematics (trigonometry and algebra), basic physics, chemistry, and business will require an average of 6 months to prepare. As stated in Knowing Your Strengths and Weaknesses, the first step is to determine your strengths and weaknesses. One of the easiest things to do, and probably one of the worst mistakes made when preparing for an examination, is to spend a lot of time studying the topics that you are strongest in. Let's face it. It's the easy thing to do. However, it will not serve you well to spend most of your time doing this. Preparing for the examination is hard work. Focus on those areas that you are weakest in.

Use the self-assessment and evaluation to develop your study plan. Determine how much time you will need to study each topic and develop a schedule to help you meet these goals. Stick to the schedule as best as you can. Cramming a lot of information at the last minute may work for a few individuals, but for the majority of people, this method does not work. When studying a particular topic, don't just rely on remembering details of the subject. Try to gain a solid understanding of each topic. The examination questions will not be questions directly from the recommended resources. They are designed to test your overall knowledge and understanding.

References and Resources

This book is designed to cover most topics listed on the examination, focusing primarily on the examination reference sheet and the equations. A list

of other references is available on the BCSP website, should you need more in-depth knowledge of a particular subject. A number of professional organizations and private companies offer ASP/CSP review courses and materials. These courses can be helpful but should not be considered all-inclusive or provide you with a complete set of knowledge of the requirements of the ASP/CSP skill set in a week's time. If you are going to spend the time and money to attend one of these courses, it is my recommendation that you do it early on in your preparation. This allows you to review and modify your preparation plans. There are study materials offered by the American Society of Safety Engineers, SPAN International, and DataChem Software, Inc., in the form of study books and compact disks with example tests. These materials average approximately $400 to $650 each. As you can see, a person preparing for the examinations has a lot of options. All of these are viable options. You must determine what works best for you, as an individual, before proceeding.

Test-Taking Strategy

Both the Safety Fundamental Examination and the Comprehensive Practice Examination contain 200 questions each. Each question is multiple choice, with four possible answers. Only one answer is correct. Each item is independent and does not rely on the correct answer to any other item. Data necessary to answer items are included in the item or in a scenario shared by several items. Your score is based on the number of scored items you correctly answer. There are no penalties assigned for wrong answers. Therefore, it is to your advantage to answer all the questions, even if you are guessing on some. However, only correct answers count toward reaching the passing score.

For you to improve your chances of passing the examination, develop a strategy for actually taking the examination. It is helpful to understand an item (question) construction. A four-choice, objectively scored examination item contains an item stem and four possible answers. The premise, or lead-in statement or question, is called the stem. One of the choices is correct and three are not. As mentioned previously, there are no penalties for incorrect answers, so for some items you may have to guess. If you do not know the answer to an item or are not sure about it, you should guess intelligently. Look for choices that you know are incorrect or do not appear as plausible as others. Choose your answer from among the remaining choices. This increases your chance of selecting a correct answer. Above all else, read the items carefully. Consider the item from the viewpoint of an examination item writer. Look for the item focus. Each item evaluates some subject or area of knowledge. Try to identify what knowledge the item is trying to test. Avoid

reading things into an item. The item can only test the information actually included. Recognize that the stems for some items may include information that is not needed for correctly answering them. Next, consider the context of the item. Often an item is framed around a particular industry or situation. Even if you do not work in that industry or have not experienced a particular situation, the item may be testing knowledge that you have. Avoid dismissing an item because of the context or the industry in which it is framed.

Use your examination time wisely. When taking your examination, complete those items first that you know or can answer quickly. Then go back to items that were difficult for you or required considerable time to read, analyze, or compute. This approach allows you to build your score as quickly as possible. You may want to go back over skipped or marked items several times. Complete the skipped items. After you have gone through the examination once, or if you are running out of time, look for items that you have not answered. Select an answer for any skipped or incomplete item. By chance alone, you can get one out of every four correct. Many times, a later item may contain the answer or at least a trigger to allow you to answer some previous question.

Go back to troublesome items. It is a good idea to mark items that you are not sure about or items that are difficult for you. After you have worked through the entire examination, go back to the marked items. Reread the items and study the choices again. You may recall some knowledge or information that you had not considered earlier and be able to answer the item correctly. You may also be able to eliminate a choice that is not correct and increase your chance of guessing the answer.

Candidates are provided with an on-screen calculator during the exam. The on-screen calculator emulates the TI-30XS scientific calculator. Test centers do not provide physical calculators or allow candidates to bring in their own.

Make sure you know how to use the provided calculator, so you do not waste time trying to understand how to use it once the examination clock starts. It is a good idea to practice working solutions and to be able to recall the correct calculator procedures. Remember, solutions to computational items are usually rounded. You should select the answer closest to the computed value.

2

Legal Aspects of the Safety Profession

The practice of safety and health professionals today has increased responsibilities from the early days of the profession. They must have more and more in-depth knowledge of not only the technical aspects of the profession, but the legal aspects, as well. Relevant legal aspects specific to the safety profession involve workers compensation, product and strict liability, and OSHA regulations and standards, just to name a few. This chapter will attempt to provide more than a cursory understanding of the legal aspects beyond mere regulations and standards. Discussions will include not only the legal framework such as an overview of the court systems, but also the legal principles that form the basis for the profession.

The basis for the legal aspects of the safety and health profession is to ensure that worker's health and welfare are paramount in all decisions. Such agencies as the Occupational Safety and Health Administration (OSHA) regulations and their counterparts globally are to establish the fundamental guidelines for employers to create and maintain safe working conditions. Examples of these regulations may include such topics as hazard communication, emergency preparedness and walking and working surfaces, which set the baseline for safety standards in the modern workplace.

This chapter will delve deeper into the legal landscape beyond these statutory regulations and encompass a broader view of legal principles, the U.S. Constitution, the court systems, common law and administrative mandates. Today's safety and health professionals must understand these legalities, how laws intersect and how judicial interpretations can shape safety practices.

United States Constitution

The beginning of all principalities of the United States legal system is established in the United States Constitution (Constitution). It is the foundation by which the government of the United States operates. The Constitution was written primarily to correct weaknesses in the original Articles of Confederation. The following quote is the Preamble to the Constitution:

> We the People of the United States, in Order to form a more perfect Union, establish Justice, insure domestic Tranquility, provide for the common defense, promote the general Welfare, and secure the Blessings

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> of Liberty to ourselves and our Posterity, do ordain and establish this Constitution for the United States of America.[1]

Since all laws created in the United States are based on the authority of the United States Constitution, it is important to understand it. There are seven (7) Articles listed in the Constitution. Each of these will be discussed throughout this chapter.

Article I

Article I of the Constitution establishes the legislative branch of the government, Congress, and provides its powers, authority, and makeup. Under Section 1, the Constitution establishes that Congress shall consist of two houses (a bicameral structure), which include the Senate and the House of Representatives. Section 2 establishes that the House of Representatives will be composed of members elected for a period of two (2) years by the people of each State. Those chosen as Representatives must have attained the age of twenty-five (25) years, have been a citizen of the United States for at least seven (7) years, and be an inhabitant of the state he or she represents at the time elected. Section 2 also determines that the number of representatives for each state is based on the population of the State. This determination is reviewed based on the census taken every ten (10) years.[2] The last census in the United States was conducted in 2020. One important note on the census that was ruled upon by the United States Supreme Court is that all residents of a State, including undocumented residents, must be included in the census. Finally, Section 2 grants the House of Representatives the exclusive authority to initiate revenue bills, which emphasizes their central role in matters of taxation and finance. This was a key issue that initiated the Revolutionary War with Great Britain, in that the Colonists were being taxed without being represented. The founding fathers thereby granted these powers to the House of Representatives. In addition, the House of Representatives has the sole power of impeachment.

When a vacancy occurs within the House of Representatives from any State, the Executive Authority of that State (the Governor of that State) shall offer up an election according to the State Constitution. The House of Representatives shall choose a Speaker of the House based on an election by members of the House.

Section 3 of Article I establishes the makeup of the Senate, which shall consist of two (2) Senators from each State regardless of the population. Each Senator will be chosen for a period of six (6) years, and each shall have one (1) vote. These Senators serve 6-year terms that are staggered in such a way that one-third of the Senate is elected every 2 years. By doing so, this promotes continuity within the Senate. The requirement to become a United States Senator is outlined in Section 3 and requires that each elected Senator

be at least 30 years old, have been a citizen of the United States for at least 9 years, and be an inhabitant of the represented State at the time of their election. This section also states that the Vice President of the United States will serve as the President of the Senate but can only cast a vote when there is a tie in the Senate. While Section 2 grants the authority to bring Impeachment, Section 3 grants the authority to try the impeachment charges brought by the House of Representatives. It further requires a two-thirds majority vote for a conviction of the charges. However, a conviction shall be limited to the removal from office.

Section 4 of Article I determines that the time, manner, and place of electing Senators and Representatives shall be vested in the States Legislatures. Section 5 provides that each chamber of Congress shall be the final judge of the election of its members. In addition, each chamber has, under the authority of Section 4, established rules of governance among its members and may punish the improper behavior of said members by a two-thirds vote. Section 6 authorizes compensation for members of the Senate and House, which are to be paid from the United States Treasury. With the exception of Treason, Felony, and Breach of Peace, members of the House and Senate shall be exempt from arrest during the Attendance at the Session of their respective chambers.

Section 7 of Article I clearly states that all Bills for raising Revenue shall be initiated within the House of Representatives, but the Senate may propose or concur with the Amendments, as with any other Bill. Section 8 established Congress's authority to lay and collect Taxes, Duties, Imposts, and Excises, to pay the Debts of the United States and provide for the common Defence (sp) and general Welfare of the United States. It further states that these Duties, Imposts, and Excises shall be uniform throughout the United States. Included within Section 8 is the authority to borrow money, regulate commerce, establish a uniform rule of Naturalization and uniform laws on the subject of bankruptcies throughout the United States, establish a money/currency system, establish a post office, call upon the military, and so on. Section 9 was primarily written to limit the powers of Congress and further emphasized the principles of individual rights and a democratic government. For modern-day purposes, Section 9 prohibits Congress from passing laws that would be retroactive in order to criminalize actions without due process. One major important prohibition in Section 9 is the prohibition to suspend the writ of habeas corpus, meaning that if a person is held in custody, the custodian of that person must produce that individual before a court. There are other prohibitions on Congress's power identified in Section 9. Section 10 primarily limits individual States from imposing restrictions, such as import taxes, on goods and services from other States. This is an important section in that it is aimed at maintaining a stable and more uniform national framework of Commerce. In addition, States are prohibited from making their own form of currency or issuing bills of credit, and so on.

Article II

Article II of the Constitution establishes the powers and limitations of the Executive Branch of the United States government. It lays the foundation for the Presidency, which is the highest office of the government. Section 1 establishes that the President shall serve a term of four (4) years by election of the States. The President will be elected by electors of each State. The number of electors from each State shall equal to the number of Senators plus the number of Representatives from that State. For example, in 2024, the State of Alabama has two (2) US Senators and seven (7) House of Representative Members. Therefore, the State of Alabama has nine Electoral votes for the upcoming presidential election. However, neither a sitting Senator nor a House of Representatives member shall serve as a States' elector.[3] The States' electors shall be selected by the government of each State. Article II Section 1 establishes that to become President of the United States a person shall have attained the age of thirty-five (35) years old, be a natural born citizen, and, except for the first President, should have been a resident of the United States for at least fourteen (14) years. Section 2 gives authority to the Presidency to serve as Commander in Chief of the Army and Navy and to make Treaties, which are consented to by a two-thirds vote of the Senate. Finally, Section 3 grants the power to fill vacancies during recess of Congress. Recess appointments are rare. However, in 2012, President Obama attempted to make several recess appointments, even when the Senate continued to hold sessions intended only to prevent recess appointments being made. This resulted in a Supreme Court case that resulted in a 9–0 vote finding in favor of the United States Senate. Section 4 establishes that the President, Vice President, and all civil Officers can only be removed from office on Impeachment for, and Conviction of Treason, Bribery, or other high Crimes and Misdemeanors. The public has seen impeachment charges brought more frequently in the past few years, beginning with President Bill Clinton and the latest with President Donald Trump. During these activities, the world saw how the Constitution worked in requiring a two-thirds vote by the US Senate. The process was meant to be somewhat difficult to ensure politics did not play a role in the removal of someone occupying these offices.

Article III

Article III of the Constitution officially established the third branch of the government, the Judicial Branch. Section 1 provides that the judicial power of the United States shall be vested in on supreme court and all such inferior courts that Congress may from time to time ordain. Section 2 lists the authority for the courts, including laws, treaties, cases in equity, etc. Section 2 specifically states that in all cases affecting Ambassadors, other public Ministers, and Consuls; the Supreme Court shall have original jurisdiction. In all other cases, the Supreme Court will have appellate jurisdiction.

Article IV

Article IV of the Constitution summarizes the relationship between the individual states. Specifically, it includes several key provisions, including the Full Faith and Credit Clause, meaning that each state must recognize and respect the public acts, records, and judicial proceedings of other states. Especially important under Article IV is the Privileges and Immunities Clause, which ensures that citizens of individual states enjoy certain fundamental rights and protections when traveling or residing in other states. This clause provides continuity and a sense of national unity. Article IV gives the general authority to admit new states to Congress. In summary, Article IV establishes the foundation for federalism, but serves as a balance between the powers of the federal government and those of the individual states, while promoting cooperation and unity between the federal government and the states.

Article V

As with any document, there may be needed changes as time goes on. As such, the founding fathers included Article V of the Constitution, which outlines the process by which the Constitution may be amended. There are two processes that can result in an amendment of the US Constitution. The first process is through a two-thirds vote in both houses of Congress, and the second is by a convention called for by two-thirds of state legislatures. If proposed, an amendment must be ratified by either three-fourths of state legislatures or by conventions in three-fourths of the states. This process is meant to ensure widespread support and agreement. For example, if a proposed amendment is presented by convention, then 38 states must agree to the amendment. If it is presented through Congress, then to pass it would require 67 Senators and 290 House of Representative members.

Article VI

Often referred to as "The Supremacy Clause," Article VI established the supremacy of federal law and the principles of national unity. By having a Supremacy Clause, the founding fathers wanted to ensure that there was a uniform legal framework across the nation and promote consistency in the application of laws. Specifically, in Article VI, federal and state officials, judges, legislators, and executives are required to take an oath of office, which pledges to support the Constitution. By doing so, this reinforced the principles of a federal system of government.

Article VII

Article VII sets forth the initiation for the ratification of the Constitution by the states. It provided that passage by 9 of the 13 colonies would serve as

formal ratification and, therefore, would be adopted. This represented two-thirds of the vote.

Amendments[4]

Currently, there are 27 Amendments that have been made to the Constitution. The first ten (10) Amendments are commonly identified as the "Bill of Rights." For brevity, they are listed as follows:

Amendment I (1791)

Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof; or abridging the freedom of speech, or of the press; or the right of the people peaceably to assemble, and to petition the Government for a redress of grievances.

Amendment II (1791)

A well-regulated Militia, being necessary to the security of a free State, the right of the people to keep and bear Arms, shall not be infringed.

Amendment III (1791)

No Soldier shall, in time of peace, be quartered in any house, without the consent of the Owner, nor in time of war, but in a manner to be prescribed by law.

Amendment IV (1791)

The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated, and no Warrants shall issue, but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized.

Amendment V (1791)

No person shall be held to answer for a capital, or otherwise infamous crime, unless on a presentment or indictment of a Grand Jury, except in cases arising in the land or naval forces, or in the Militia, when in actual service in time of War or public danger; nor shall any person be subject for the same offense to be twice put in jeopardy of life or limb; nor shall be compelled in any criminal case to be a witness against himself, nor be deprived of life,

liberty, or property, without due process of law; nor shall private property be taken for public use, without just compensation.

Amendment VI (1791)

In all criminal prosecutions, the accused shall enjoy the right to a speedy and public trial, by an impartial jury of the State and district wherein the crime shall have been committed, which district shall have been previously ascertained by law, and to be informed of the nature and cause of the accusation; to be confronted with the witnesses against him; to have compulsory process for obtaining witnesses in his favor, and to have the Assistance of Counsel for his defense.

In Suits at common law, where the value in controversy shall exceed 20 dollars, the right of trial by jury shall be preserved, and no fact tried by a jury shall be otherwise re-examined in any Court of the United States, than according to the rules of the common law.

Amendment VIII (1791)

Excessive bail shall not be required, nor excessive fines imposed, nor cruel and unusual punishments inflicted.

Amendment IX (1791)

The enumeration in the Constitution, of certain rights, shall not be construed to deny or disparage others retained by the people.

Amendment X (1791)

The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States, respectively, or to the people.

Amendment XI (1795/1798)

The Judicial power of the United States shall not be construed to extend to any suit in law or equity, commenced or prosecuted against one of the United States by Citizens of another State, or by Citizens or Subjects of any Foreign State.

Amendment XII (1804)

The Electors shall meet in their respective states and vote by ballot for President and Vice-President, one of whom, at least, shall not be an inhabitant of the same state with themselves; they shall name in their ballots the person voted for as President, and in distinct ballots the person voted for as Vice-President, and they shall make distinct lists of all persons voted for as

President, and of all persons voted for as Vice-President, and of the number of votes for each, which lists they shall sign and certify, and transmit sealed to the seat of the government of the United States, directed to the President of the Senate— the President of the Senate shall, in the presence of the Senate and House of Representatives, open all the certificates and the votes shall then be counted—the person having the greatest number of votes for President, shall be the President, if such number be a majority of the whole number of Electors appointed; and if no person have such majority, then from the persons having the highest numbers not exceeding three on the list of those voted for as President, the House of Representatives shall choose immediately, by ballot, the President. But in choosing the President, the votes shall be taken by states, the representation from each state having one vote; a quorum for this purpose shall consist of a member or members from two-thirds of the states, and a majority of all the states shall be necessary to a choice. And if the House of Representatives shall not choose a President whenever the right of choice shall devolve upon them, before the fourth day of March next following, then the Vice President shall act as President, as in the case of the death or other constitutional disability of the President—the person having the greatest number of votes as Vice President, shall be the Vice President, if such number be a majority of the whole number of Electors appointed, and if no person have a majority, then from the two highest numbers on the list, the Senate shall choose the Vice President; a quorum for the purpose shall consist of two-thirds of the whole number of Senators, and a majority of the whole number shall be necessary to a choice. But no person constitutionally ineligible to the office of President shall be eligible to that of Vice President of the United States.

Amendment XIII (1865)

Section 1. Neither slavery nor involuntary servitude, except as a punishment for crime whereof the party shall have been duly convicted, shall exist within the United States, or any place subject to their jurisdiction.

Section 2. Congress shall have power to enforce this article by appropriate legislation.

Amendment XIV (1868)

Section 1. All persons born or naturalized in the United States, and subject to the jurisdiction thereof, are citizens of the United States and of the State wherein they reside. No State shall make or enforce any law which shall abridge the privileges or immunities of citizens of the United States; nor shall any State deprive any person of life, liberty, or property, without due process of law; nor deny to any person within its jurisdiction the equal protection of the laws.

Section 2. Representatives shall be apportioned among the several States according to their respective numbers, counting the whole number of persons in each State, excluding Indians not taxed. But when the right to vote at any election for the choice of electors for President and Vice President of the United States, Representatives in Congress, the Executive and Judicial officers of a State, or the members of the Legislature thereof, is denied to any of the male inhabitants of such State, being 21 years of age, and citizens of the United States, or in any way abridged, except for participation in rebellion, or other crime, the basis of representation therein shall be reduced in the proportion which the number of such male citizens shall bear to the whole number of male citizens 21 years of age in such State.

Section 3. No person shall be a Senator or Representative in Congress, or elector of President and Vice President, or hold any office, civil or military, under the United States, or under any State, who, having previously taken an oath, as a member of Congress, or as an officer of the United States, or as a member of any State legislature, or as an executive or judicial officer of any State, to support the Constitution of the United States, shall have engaged in insurrection or rebellion against the same, or given aid or comfort to the enemies thereof. But Congress may, by a vote of two-thirds of each House, remove such disability.

Section 4. The validity of the public debt of the United States, authorized by law, including debts incurred for payment of pensions and bounties for services in suppressing insurrection or rebellion, shall not be questioned. But neither the United States nor any State shall assume or pay any debt or obligation incurred in aid of insurrection or rebellion against the United States, or any claim for the loss or emancipation of any slave; but all such debts, obligations, and claims shall be held illegal and void.

Section 5. The Congress shall have power to enforce, by appropriate legislation, the provisions of this article.

Amendment XV (1870)

Section 1. The right of citizens of the United States to vote shall not be denied or abridged by the United States or by any State on account of race, color, or previous condition of servitude.

Section 2. The Congress shall have power to enforce this article by appropriate legislation.

Amendment XVI (1913)

The Congress shall have power to lay and collect taxes on incomes, from whatever source derived, without apportionment among the several States, and without regard to any census or enumeration.

Amendment XVII (1913)

The Senate of the United States shall be composed of two Senators from each State, elected by the people thereof, for 6 years; and each Senator shall have one vote. The electors in each State shall have the qualifications requisite for electors of the most numerous branch of the State legislatures.

When vacancies happen in the representation of any State in the Senate, the executive authority of such State shall issue writs of election to fill such vacancies, provided that the legislature of any State may empower the executive thereof to make temporary appointments until the people fill the vacancies by election as the legislature may direct.

This amendment shall not be so construed as to affect the election or term of any Senator chosen before it becomes valid as part of the Constitution.

Amendment XVIII (1919)

Section 1. After 1 year from the ratification of this article, the manufacture, sale, or transportation of intoxicating liquors within, the importation thereof into, or the exportation thereof from the United States and all territory subject to the jurisdiction thereof for beverage purposes is hereby prohibited.

Section 2. The Congress and the several States shall have concurrent power to enforce this article by appropriate legislation.

Section 3. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by the legislatures of the several States, as provided in the Constitution, within 7 years from the date of the submission hereof to the States by the Congress.

Amendment XIX (1920)

The right of citizens of the United States to vote shall not be denied or abridged by the United States or by any State on account of sex.

Congress shall have power to enforce this article by appropriate legislation.

Amendment XX (1933)

Section 1. The terms of the President and Vice President shall end at noon on the 20th day of January, and the terms of Senators and Representatives at noon on the third day of January, of the years in which such terms would have ended if this article had not been ratified; and the terms of their successors shall then begin.

Section 2. The Congress shall assemble at least once every year, and such meeting shall begin at noon on the third day of January, unless they shall by law appoint a different day.

Section 3. If, at the time fixed for the beginning of the term of the President, the President elect shall have died, the Vice President elect shall become President. If a President shall not have been chosen before the time fixed for

the beginning of his term, or if the President elect shall have failed to qualify, then the Vice President elect shall act as President until a President shall have qualified; and the Congress may by law provide for the case wherein neither a President elect nor a Vice President elect shall have qualified, declaring who shall then act as President, or the manner in which one who is to act shall be selected, and such person shall act accordingly until a President or Vice President shall have qualified.

Section 4. The Congress may by law provide for the case of the death of any of the persons from whom the House of Representatives may choose a President whenever the right of choice shall have devolved upon them, and for the case of the death of any of the persons from whom the Senate may choose a Vice President whenever the right of choice shall have devolved upon them.

Section 5. Sections 1 and 2 shall take effect on the 15th day of October following the ratification of this article.

Section 6. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by the legislatures of three-fourths of the several States within 7 years from the date of its submission.

Amendment XXI (1933)

Section 1. The 18th article of amendment to the Constitution of the United States is hereby repealed.

Section 2. The transportation or importation into any State, Territory, or possession of the United States for delivery or use therein of intoxicating liquors, in violation of the laws thereof, is hereby prohibited.

Section 3. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by conventions in the several States, as provided in the Constitution, within 7 years from the date of the submission hereof to the States by the Congress.

Amendment XXII (1951)

Section 1. No person shall be elected to the office of the President more than twice, and no person who has held the office of President, or acted as President, for more than 2 years of a term to which some other person was elected President shall be elected to the office of the President more than once. But this Article shall not apply to any person holding the office of President, when this Article was proposed by the Congress, and shall not prevent any person who may be holding the office of President, or acting as President, during the term within which this Article becomes operative from holding the office of President or acting as President during the remainder of such term.

Section 2. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by the legislatures of three-fourths of the several States within 7 years from the date of its submission to the States by the Congress.

Amendment XXIII (1961)

Section 1. The District constituting the seat of Government of the United States shall appoint in such manner as the Congress may direct:

A number of electors of President and Vice President equal to the whole number of Senators and Representatives in Congress to which the District would be entitled if it were a State, but in no event more than the least populous State; they shall be in addition to those appointed by the States, but they shall be considered, for the purposes of the election of President and Vice President, to be electors appointed by a State; and they shall meet in the District and perform such duties as provided by the 12th article of amendment.

Section 2. The Congress shall have power to enforce this article by appropriate legislation.

Amendment XXIV (1964)

Section 1. The right of citizens of the United States to vote in any primary or other election for President or Vice President for electors for President or Vice President, or for Senator or Representative in Congress, shall not be denied or abridged by the United States or any State by reason of failure to pay any poll tax or other tax.

Section 2. The Congress shall have power to enforce this article by appropriate legislation.

Amendment XXV (1967)

Section 1. In case of the removal of the President from office or of his death or resignation, the Vice President shall become President.

Section 2. Whenever there is a vacancy in the office of the Vice President, the President shall nominate a Vice President who shall take office upon confirmation by a majority vote of both Houses of Congress.

Section 3. Whenever the President transmits to the President pro tempore of the Senate and the Speaker of the House of Representatives his written declaration that he is unable to discharge the powers and duties of his office, and until he transmits to them a written declaration to the contrary, such powers and duties shall be discharged by the Vice President as Acting President.

Section 4. Whenever the Vice President and a majority of either the principal officers of the executive departments or of such other body as Congress may by law provide, transmit to the President pro tempore of the Senate and the Speaker of the House of Representatives their written declaration that the President is unable to discharge the powers and duties of his office, the Vice President shall immediately assume the powers and duties of the office as Acting President.

Thereafter, when the President transmits to the President pro tempore of the Senate and the Speaker of the House of Representatives his written declaration that no inability exists, he shall resume the powers and duties of his office unless the Vice President and a majority of either the principal officers of the executive department or of such other body as Congress may by law provide, transmit within 4 days to the President pro tempore of the Senate and the Speaker of the House of Representatives their written declaration that the President is unable to discharge the powers and duties of his office. Thereupon Congress shall decide the issue, assembling within 48 h for that purpose if not in session. If the Congress, within 21 days after receipt of the latter written declaration, or, if Congress is not in session, within 21 days after Congress is required to assemble, determines by a two-thirds vote of both Houses that the President is unable to discharge the powers and duties of his office, the Vice President shall continue to discharge the same as Acting President; otherwise, the President shall resume the powers and duties of his office.

Amendment XXVI (1971)

Section 1. The right of citizens of the United States, who are 18 years of age or older, to vote shall not be denied or abridged by the United States or by any State on account of age.

Section 2. The Congress shall have power to enforce this article by appropriate legislation.

Amendment XXVII (1992)

No law varying the compensation for the services of the Senators and Representatives shall take effect, until an election of Representatives shall have intervened.

Court System Overview

As outlined in Article III of the United States Constitution, the United States has a court system that consists of both federal and state courts. Whether a court system is federal or state, they all follow a similar makeup, with each consisting of an initial court (usually a district court), an appeals court or circuit court, and a higher or Supreme Court. The Supreme Court is typically the highest court and final decision authority for most cases. There are some variations and exceptions in some states. However, in general, this is the typical court system makeup. At the District Court level, there may be specialty courts, such as civil or criminal courts.

Federal Court System

The federal court system consists of a Supreme Court (the court of last resort), three Courts of Appeals, US Court of Military Appeals, US Courts of Appeals of which there are currently 12 courts, and the US Court of Appeals for the Federal Circuit. The US Court of Military Appeals has subordinate military courts. The US Courts of Appeals have subordinate courts that include the US Tax Courts, Territorial Courts, Court of the District of Columbia, District Courts (which currently have 94 courts), and the Appeals Courts from Federal Regulatory Agencies. The US Court of Appeals for the Federal Circuit includes the US Claims Court, the US Court of Veterans Appeals, and the US Court of International Trade as subordinate courts. This system is represented graphically in Figure 2.1.

State Court System

State courts are set up in a similar fashion to federal courts. However, there may be variations from state to state. Many states will have specialty courts such as "drug courts," juvenile courts, etc. An example of a state court system is identified in Figure 2.2.

Contrary to popular legal drama shows on television or portrayed in the media, very few legal cases (also known as "suits") ever see the inside of a courtroom. Ninety-seven percent (97%) of legal cases are settled without ever seeing a court. This means that the remaining three percent (3%) will wait months or years to get to see a judge. There are some exceptions to these statistics, but they are a rarity.

To fully understand the legal system of the United States, it is necessary to have a basic knowledge of how a case ever gets brought before a court in the first place. The court must have one of the following to hear a case:

- Subject matter jurisdiction
- Personal jurisdiction over the parties
- The court must comply with due process
  1. Notification (Notice)
  2. Opportunity to be heard
  3. Hearing

Jurisdiction is determined as follows:

- Original jurisdiction—meaning that the court has the right to hear a case for the first time. Jurisdictional levels include the federal, state, or local levels.
- Appellate jurisdiction means that the court has the right to hear a case on appeal if the law has been applied unfairly or incorrectly. They are not designed to hear new evidence or new legal theories.

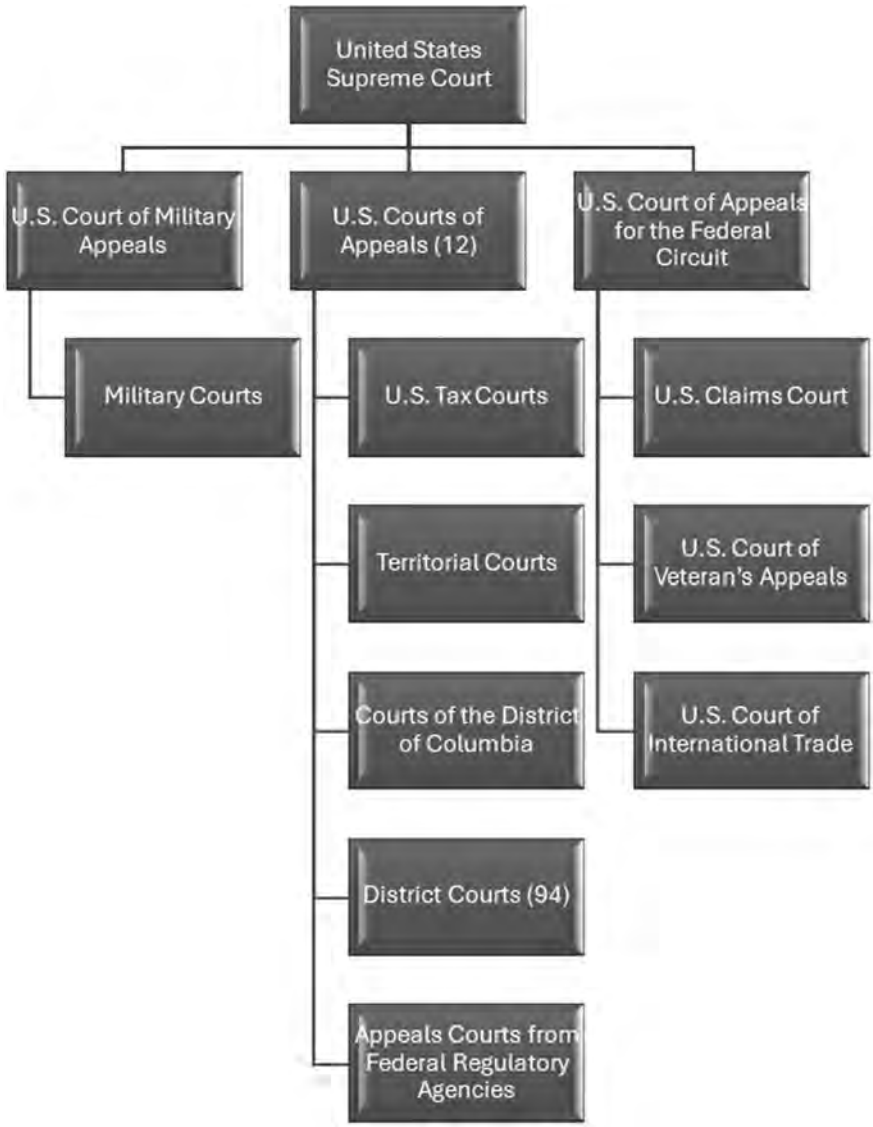


FIGURE 2.1
United States Federal Court System (Source: Yates, W. David, 2024).

- Exclusive jurisdiction is assigned by the US Constitution, and only federal courts can hear certain cases, such as cases involving national laws, the federal government, or other governments (State or Foreign).
- Concurrent jurisdiction means cases that can be decided in state or federal courts.

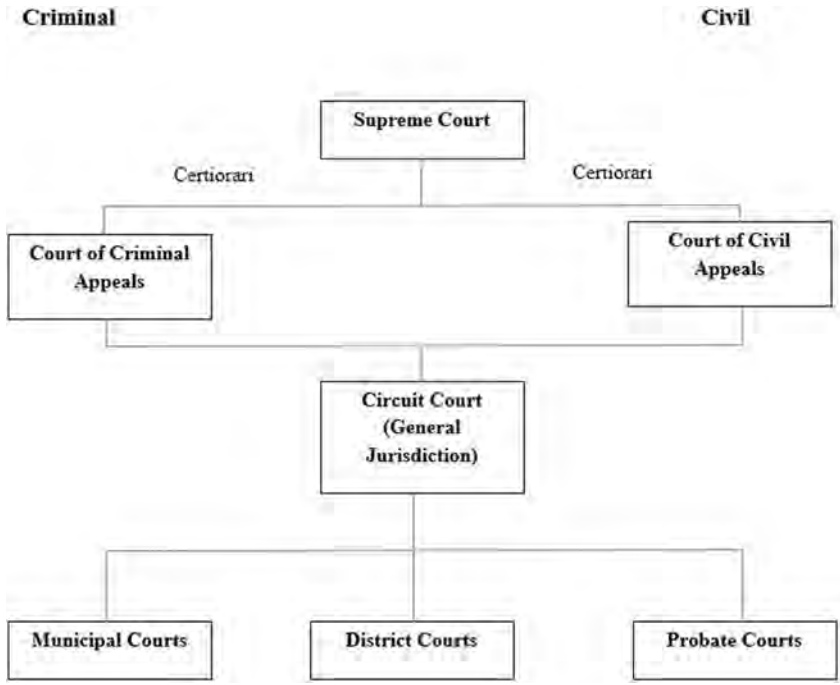


FIGURE 2.2
Example State Court System (Source: Yates, W. David, 2024).

The Supreme Court of the United States has original but not exclusive jurisdiction of cases involving ambassadors, diplomats, etc. The Court may hear cases by "writ of certiorari," meaning that it is a discretionary review and is not obligated to hear cases on appeal. Federal courts, in general, will hear cases involving federal laws. Unless the federal court has original or appellate jurisdiction, the cases that are heard in federal court are:

1. Federal questions. An example of a federal question is if a party to a suit is claiming a violation of a constitutional right, such as freedom of speech, freedom of religion, etc.
2. Diversity of parties. This means that all parties are from different states. For example, if Party A is from New Jersey and Party B is from New York and they have a dispute, then they have diversity of parties.
   a. This dispute must also be valued at more than $75,000 in monetary terms.
   b. Both diversity of party and $75,000 monetary value must be met for these cases to be heard in federal court.

An extremely important case involving the United States' Courts is that of *Madison v. Marbury*, which was heard in 1803. William Marbury had been given a judicial appointment by President John Adams. Unfortunately for Mr Marbury, the judicial appointment was not delivered to him before the end of President Adams' term of office. Mr Marbury petitioned the Supreme Court to force the new administration to deliver the appointment under the Judiciary Act of 1789. The Court ultimately held that the relevant portions of the Judiciary Act of 1789 were unconstitutional and therefore ruled against Mr Marbury. However, the decision in *Marbury* confirmed the principle of judicial review. This meant that the Court had the power to declare laws unconstitutional. This power is frequently used by today's Supreme Court, especially in the enforcement of administrative law decisions.

Types of Law

So far in this chapter, the authority of the government, including the Legislative, Executive, and Judicial branches, along with the court system and its authority, has been discussed. Now, the methods by which laws are made will be discussed. The types of laws that are important for this discussion include Case Law, Statutory Law, and Administrative Law. Each of these is important in the practice of safety. Many people think that laws are all made by either state or federal legislatures, but this is not true.

Case Law

Case law is also known as judge-made or case-made law. Case laws are based on judicial decisions, which are derived from actual cases where legal questions are interpreted at the appeals level. An important terminology that should be defined at this point is that of "stare decisis." One of the guiding principles of a legal system is to have fairness and consistency in decisions. Stare decisis is a principle that means "let the decision stand." Stare decision is based on the guiding principle that precedents and decisions have already been made in previous cases and that they should be honored in all future rulings, unless a case can be made that the decision was made in error or from a varying viewpoint. In the case of federal courts, stare decisis will be followed regardless of the actual court a case is brought in. For example, if a case that results in a precedent is ruled in the 5th Circuit, any future decisions in other federal courts will be based on this ruling. A specific environmental precedent that resulted in a stare decisis ruling is *Sackett v. United States Environmental Protection Agency.* This was a case that resulted in a new definition of "navigable waters" being decided by the Supreme Court. The Court in its ruling defined (unanimously) that the EPA's wetlands regulatory jurisdiction is limited to wetlands with a continuous surface connection to water of the United States.

Public law deals with the relationship between the government and citizens. Examples of public law include criminal law, constitutional law, administrative law, and international law.

Administrative Law

Administrative laws are those laws created by administrative agencies. Examples of these may include the standards and regulations created by the Occupational Safety and Health Administration (OSHA) and the United States Environmental Protection Agency (USEPA). These laws are codified in the *Code of Federal Regulations*. Many of these agencies have tried to increase their authority in recent years and have had to be reigned in by the United States Supreme Court for being overreaching or overly broad.

Statutory Law

Statutory laws are those laws that are created by either Federal or State legislators. The Federal laws are codified in the *United States Codes*. In addition to being enacted by Congress, these "bills" are signed into law by the Executive branch.

Torts

Torts is an overall classification of civil causes that usually result in a payment to a private party (normally referred to as the plaintiff) for an injury caused by a defendant. Tort laws are generally the result of case law precedents, but more recently, many of them are becoming codified by statute. Understanding torts is important to the safety professional. While the majority of workplace injuries cannot be litigated as a tort, unless gross negligence on the part of the company has been proven (discussed later in this chapter), this does not prevent visitors and contractors to the site from bringing a civil cause of action under tort. An example of this would be a visitor visiting your workplace and, while walking to the building, she steps into a hole in the parking lot and breaks her leg. She can now bring a cause of action based on a negligent tort.

A **tort** is an act or omission that causes an injury or harm to another. For a plaintiff (the party bringing the case) to prevail in a civil "torts" case, they must prove each of the four elements. Those four elements are:

- **Duty** of care
- **Breach** of that duty

- The breach was the **cause** of the injury or harm
- There was actual damage resulting from the breach

If the defendant can prove any one or more of these elements to be missing, the defendant will prevail. When, and if, a tort case gets to court, the parties must prove their facts to the juries, which are the triers of fact. In other words, the juries will determine which side is more compelling regarding what happened, whether the plaintiff breached the duty of care, and whether that breach was the cause of the damages claimed. The judge decides the issues of law, such as whether the plaintiff had a duty of care, what evidence can be used, what standard of care was appropriate for the case, and under what statute.

Types of Damages

As with any court case involving torts, the primary remedy (what is being sought) involves money. The following are the types of damages:

- **Nominal damages:** These consist of a small sum of money awarded to the plaintiff in order to vindicate rights, make the judgment available as a matter of record to prevent the defendant from acquiring prescriptive rights, and carry a part of the costs of the action. The amount of the award, as long as it is trivial, is unimportant.
- **Compensatory damages:** These are intended to represent the closest possible financial equivalent of the loss or harm suffered by the plaintiff, to make the plaintiff whole again, and to restore the plaintiff to the position the plaintiff was in before the tort occurred.
  1. Special: Lost wages, lost future wages, hospital and medical costs
  2. General: pain and suffering, mental anguish, social and family issues
- **Punitive damages:** These are an additional sum, over and above the compensation of the plaintiff, awarded to punish the defendant, to make an example of the defendant, and to deter the defendant and others from engaging in similar tortuous conduct.

Types of Torts

Torts fall into three basic categories:

- Intentional torts (intentionally hitting someone)
- Negligent torts (failing to obey a traffic rule and causing an accident)
- Strict liability torts (liability from manufacturing or selling defective products)

Intentional Torts

Specific intentional torts include[5]the following:

- **Assault**—An act by a person done with the intent to create apprehension in another. An example of assault would be a person throwing an object at another person with the intent to cause harm, regardless of whether the object makes contact or not.
- **Battery**—Harmful or offensive unwanted contact, either direct or indirect with a person. Examples include pushing, shoving, spitting, hugging, touching, or even kissing can be considered batteries.
- **False imprisonment**—An example of false imprisonment can include forcing someone into a room through threats of harm or getting them to stay somewhere by lying or deceiving them.
- **Intentional and reckless infliction of emotional distress**—Examples of Intentional Infliction of Emotional Distress would include continuous verbal insults, racial insults, and sex discrimination. An example of Reckless Infliction of Emotional Distress would be a funeral home that lost a family member's remains before the funeral.
- **Trespass to land**—Intentionally or unintentionally crossing onto another person's property without permission. An example would be walking onto a person's property without permission while hunting. An example of a business trespass to land would be storing materials on another's property. Finally, if a person causes an object, such as a golf ball, to cross onto another person's property, this could be considered a trespass.
- **Trespass to chattel**—An intentional interference with another person's lawful possession of personal property. An example would be a student who takes another's textbook and places it in their backpack, then leaves without permission. The second student is interfering with the owner's use of the textbook.
- **Conversion**—Conversion is the taking of another's property, without the owner's consent, and making it their own. An example of conversion is that a person finds a necklace on the ground, believing it to be abandoned, with the intent to sell the necklace.
- **Defamation**—Defamation is the harming of another person's reputation through libel (written) or slander (spoken) communications.

Defense to Intentional Torts

There are four basic defenses to avoid liability for intentional torts, including:

- **Self-defense and defense of others**—(This defense is based on the premise that a reasonable amount of force was necessary to defend oneself or another from being harmed or killed. Some states have a "duty-to-retreat" law requiring the potential victim to take all avenues possible to retreat. An example of this would be a burglar entering your home without permission. The homeowner would have a duty to escape before protecting themselves with physical or deadly force. Other states have a "stand-your-ground" or Castle Doctrine law that does not include the duty to retreat as part of defending oneself.)
- **Defense of property**—(To use the defense of property defense, the defendant must show that force was used against a wrongdoer and that the amount of force was reasonable to protect their property. However, to be successful when deadly force is involved, the defendant must prove that there was an actual danger to the defendant or others on the property.)
- **Consent**—Consent is a common defense to intentional torts and asserts that the person affected by the offense gave permission to the "offender" to engage in the otherwise wrongful activity. This consent may be expressed, which means clear communication either verbally or written; implied by actions or silence; or assumed since the offended party has consented in the past.
- **Necessity**—The defense of necessity mainly involves trespass or conversion and occurs when the offending party must commit the offense or risk greater harm to themselves or others. An example of necessity is when a person is caught in a tremendous storm and has no shelter. To ensure their survival, the offending person may take shelter in an unoccupied building owned by others without permission.

There is a fifth defense that may sometimes be used referred to as "Justification," which is also referred to as "privilege." An example of justification (in some states) is that of a parent spanking a child. Courts have upheld the right of a parent to reasonably punish their children, including corporal punishment.

Negligent Tort Defenses

A negligent tort is a lawsuit by a plaintiff against another individual or organization for causing harm or injury due to their negligent behavior. Unlike intentional torts, negligent torts are caused by a lack of reasonable care. Some examples of negligent torts include:

- Slips, trips, and falls resulting from poorly maintained facilities.
- Automobile accident caused by reckless driving.

- Injuries resulting from improper equipment operation or maintenance.
- Medical injuries from doctors failing to take reasonable precautions.

An important issue in tort cases to remember is that in criminal cases, the evidence against a criminal defendant requires **proof beyond a reasonable doubt**. Under tort claims, cases are decided using **the preponderance of the evidence standard**. This means that a plaintiff must prove their case was likely to occur with greater than 50% certainty.

Tort Defenses

Contributory negligence: An affirmative defense that substantially proves the plaintiff was responsible for his/her own accident or injury. States having a contributory negligence awards. In this case, if the plaintiff is even slightly responsible for the cause of the injury or accident, they may not recover.
Comparative negligence: In some states, awards may be made based on the percentage of causation. For example, if the plaintiff contributed to their own accident (e.g., not wearing a seat belt, etc.), then the award amount, if any, will be based on those percentages. If a jury awards the plaintiff $1,000,000 but finds that the plaintiff was 50% responsible for the injury, the award will only be $500,000.
Modified comparative negligence: In states that have a modified comparative award system, plaintiffs may recover if the defendant caused at least 50% of the accident or injury.

Gross Negligence

Gross negligence is a legal concept that every safety professional should be aware of and understand its importance. Gross negligence is an elevated degree of negligence that represents an extreme departure from the normal standard of care. Gross negligence can be willful, wanton, or reckless conduct that affects life or property.[6]

The primary reason that safety professionals must understand its importance is that work-related injuries must run through the Workers' Compensation claim system, *unless* gross negligence can be proven. When gross negligence is proven, a plaintiff may bring a suit outside the Workers' Compensation system as a tort action. To prove gross negligence, the plaintiff must prove that the defendant committed negligence and that they consciously knew or should have known that their negligent actions would or would likely cause someone harm.

Strict Liability

Strict Liability is a legal term representing a form of "tort."

A plaintiff in a *strict liability* case, however, does not have to prove a breach of duty. In a strict liability case, the defendant must pay damages

even though the defendant neither intentionally acted nor failed to live up to the objective standard of reasonable care that traditionally has been at the root of negligence law, meaning, again, that they do not have to meet all the elements of a negligence suit. Strict liability holds that there are some acts or conditions that are so hazardous, by their nature, that negligence is not needed. Examples of strict liability include animals, blasting operations, etc.

When a court imposes strict liability on a defendant, the defendant must pay damages even though the defendant neither intentionally acted nor failed to live up to the objective standard of reasonable care that traditionally has been at the root of negligence law. Strict liability requires:

- Absolute duty to make safe
- Breach (fact-based fault)
- Cause
- Harm

Animals

In the case of animals, an example is that of personal pets that are listed on a dangerous breed list by most insurance companies, such as Rottweilers, pit bulls, Dobermanns, German Shepherds, Huskies, Chow Chows, Great Danes, St. Bernards, etc. The owner, keeper, or harborer of one of these animals may be held liable regardless of the care taken if one of them attacks another person.

Abnormally Dangerous Activities

There are six elements to consider regarding abnormally dangerous activities:

1. Existence of a high degree of risk of some harm to the person, land, chattels, or others.
2. The likelihood that the harm resulting from it will be great.
3. Inability to eliminate risk by the exercise of reasonable care.
4. The extent to which the activity is not a matter of common usage.
5. Inappropriateness of the activity to the place where it is carried out.
6. The extent to which its value to the community is outweighed by its dangerous attributes.

While all these factors are important and should be considered, ordinarily the presence of more than one factor, but not all of them, will be necessary to declare the activity as ultra-hazardous as a matter of law so as to hold the actor strictly liable. Ultra-hazardous and abnormally dangerous activities are one and the same.

Defenses to Strict Liability

1. **Act of God**—(Earthquake, tornado). However, in some cases, such as a tornado in Alabama or an earthquake in Los Angeles, CA, would not be considered an Act of God because they are foreseeable. It's only an Act of God if you can't foresee it. In other words, both of the examples provided here are foreseeable or predictable (not when, but that they do occur frequently).

1. **Last clear chance doctrine**: The last clear chance doctrine is an affirmative defense usually asserted by a defendant to attempt to defeat a negligence claim. This defense essentially provides that the plaintiff had the last opportunity to prevent the harm that occurred and therefore recovery should be barred or reduced.
2. **Comparative math in comparative states**: This will be discussed later in this chapter.
3. **Assumption of risk/implied consent:** Must have four (4) elements:
   a. Voluntary encountering
   b. Actual knowledge of the particular risk
   c. Voluntary assumption of the risk
   d. Appreciation of the magnitude of the risk
4. **Not contributory**

Limitations to strict liability are only limited to those issues that can be foreseen by a reasonable person.

There is no Res Ipsa Loquitor in Strict Liability**.** *Res Ipsa Loquitor* is Latin for "the thing speaks for itself," a doctrine of law that one is presumed to be negligent if he/she/it had exclusive control of whatever caused the injury even though there is no specific evidence of an act of negligence, and without negligence, the accident would not have happened. Examples: (a) a load of bricks on the roof of a building being constructed by Highrise Construction Co. falls and injures Paul Pedestrian below, and Highrise is liable for Pedestrian's injury even though no one saw the load fall. (b) While under anesthetic, Isabel Patient's nerve in her arm is damaged although it was not part of the surgical procedure, and she is unaware of which of a dozen medical people in the room caused the damage. Under res ipsa loquitur, all those connected with the operation are liable for negligence. Lawyers often shorten the doctrine to "res ips," and find it a handy shorthand for a complex doctrine.

Products Liability

"Products Liability" is the umbrella term for the liability of a manufacturer, seller, or other supplier of chattels, to one with whom he is not in privity of contract and who suffers physical harm caused by the chattel.

Everything you can think of is a product (food, drink, drugs, clothes, cars, pet food, medicine, hair dye, everything you use daily). Privity is generally not required. Privity (Privity of Contract) is the common law principle that requires a contract, which further imposes obligations and rights on those covered under the contract.

Three theories regarding Products Liability:

- **Negligence**: There are five available sub-theories (manufacture, design, inspect, warning, and parts)—(DUTY, BREACH, CAUSATION, and DAMAGES) (All foreseeable)---Defenses to Negligence---contributory, comparative, assumption of risk, misuse, and alteration)
- **Strict liability**: (a) Dangerous defective product, unreasonably dangerous to the ultimate user or consumer; (b) when it leaves each defendant's control; (c) without alteration (substantial change); (d) defendant is a seller in goods of that kind (in the commercial chain); (e) the claimed defect caused the injury (any foreseeable plaintiff; no privity required; DEFENSES (Not Contributory), but comparative principles in comparative states, assumption of risk, alteration, failure to follow instructions).
- **Warranty theory**: Two varieties (Express and Implied)—Express (Specific guarantee); Implied warranty of merchantability (comes from a merchant)—the product will do what it is supposed to do. Must come from a merchant, not per seller.
- **Implied warranty**:
  1. Seller knew of buyer's needs
  2. Seller recommended
  3. Buyer relied on what the seller suggested

Vicarious Liability

Vicarious liability, also termed imputed liability, is a general legal concept that holds a person or company responsible for the actions committed by others, such as their employees. Vicarious liability is also a type of strict liability. In a vicarious liability suit, the defendant can be held liable even without proving negligence. For example, if a food server drops a pot of hot coffee on a patron and causes damage, the restaurant owner is responsible for the server's actions.

Types and Examples of Vicarious Liability

- **Employer–Employee**: An employer can be vicariously liable for the harmful actions of an employee if the employee (a) was on the clock,

(b) caused harm while performing an activity he was hired to perform, and (c) somehow benefited from the activity the employee was performing at the time of the injury. The example above was a clear instance of the employer–employee relationship. Another example that may not be as clear is an employee (a sales representative) going to meet a client. While en route to the designated destination, the employee decided to deviate and stop at a park for lunch. While pulling into the park, the sales representative strikes a pedestrian, causing a broken leg. Even though this would be a deviation from the assigned duties, courts have held employers liable for such injuries because the representative was considered to be performing their basic assigned duties.

- **Parent–Child**: In some cases, parents may be held accountable for the actions of their children who injure others. State laws may vary as to when parents can be held accountable. For example, an 8-year-old child saw a woman at a family gathering about to sit down and pulled the chair out from beneath her at the last moment, causing damage to her spine. The parents may be held liable for the actions of their child in this scenario.

Factors Helpful in Determining Whether an Employee Embarked on a Slight or Substantial Deviation from Employment

Factors helpful in determining whether an employee has embarked on a slight or substantial deviation from employment:

- The employee's intent.
- The nature, time, and place of the deviation.
- The time consumed in the deviation.
- The work for which the employee was hired.
- The incidental acts reasonably expected by the employer.
- The freedom allowed the employee to perform his job responsibilities.

Key Information to Remember on Legal Aspects of the Safety Professional

1. The beginning of all principalities of the United States legal system is established in the United States Constitution (Constitution).
2. The Court must have either Subject Matter Jurisdiction or Personal Jurisdiction over the parties to hear a case.

3. An extremely important case involving the United States' Courts is that of *Madison v. Marbury*, which was heard in 1803.
4. Case law is also known as judge-made or case-made law. Case laws are based on judicial decisions, which are derived from actual cases where legal questions are interpreted at the appeals level.
5. An important terminology that should be defined at this point is that of "stare decisis."
6. Administrative laws are those laws created by administrative agencies.
7. Statutory laws are those laws that are created by either Federal or State legislators.
8. Torts is an overall classification of civil causes that usually result in a payment to a private party (normally referred to as the plaintiff) for an injury caused by a defendant.
9. Three types of damages are nominal damages, contributory damages, and punitive damages.
10. For a court case to get to Federal Court, the issue must be either a federal question or diversity of parties. If diversity of party, then the issue must be greater than $75,000.
11. A plaintiff in a *strict liability* case, however, does not have to prove a breach of duty.
12. Vicarious liability, also termed imputed liability, is a general legal concept that holds a person or company responsible for the actions committed by others, such as their employees.

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3

Recording and Reporting Occupational Injuries and Illnesses

Chapter 3 will be a deep dive into the nuances of 29 CFR 1904, Recording and Reporting Occupational Injuries and Illnesses. The recording and reporting of occupational injuries is required by both the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration. While there are a lot of similarities between the two agencies, there are some critical differences between the two. For purposes of this Chapter, the primary focus and rules discussed will be limited to those required under 29 CFR 1904 that applies only to OSHA-regulated sites.

Partial Exemptions

The first question that must be asked is, "Is my employer required to report and record occupational injuries?" Of course, the simple answer is that all injuries and incidents should be recorded, documented, and investigated to prevent future injuries of a similar nature. However, under OSHA, only those employers with more than 10 employees or those employers with fewer than 10 employees who have been notified in writing by OSHA or the Bureau of Labor Statistics are required to keep occupational injury records and required to report. Keep in mind that the number of employees is based on the number of employees at all sites within the organization. By way of example, if you have a branch fabrication shop that operates independently with eight (8) employees, and another company-affiliated facility with seven (7) employees, both locations are required to keep records and report occupational injuries and illnesses.

Recording Criteria

Work-Relatedness

The first requirement for an employer after an injury or illness has been reported is to ensure that the employee has received the proper medical care based on the nature of the injury. Once it has been established that the

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employee is stable and his or her injuries/illnesses have been stabilized, the next step is to determine if the injury is related to an event or exposure in the work environment. This is not always a simple determination. OSHA has determined that if the injury or illness was caused by an event or exposure in the work environment or contributed to the resulting condition or significantly aggravated a pre-existing injury or illness, it is considered work-related. One important concept that must be understood is that ***reportability*** to OSHA should not be confused with ***compensability*** under Workers' Compensation laws. An injury may be deemed non-reportable under OSHA and at the same time considered compensable under Workers' Compensation laws.

It is important at this point to define the "work environment." OSHA defines the work environment as "the establishment or other locations where one or more employees are working or are present as a condition of their employment." The work environment includes not only physical locations but also the equipment or materials used by the employee during the course of his or her work (29 CFR 1904). An example to illustrate a work environment that is not typical would be a member of the Sales Team who flies on a commercial airline to meet a customer. During the trip, the Sales Team Member steps off the plane stairs onto the tarmac, slips, and falls, which results in a hairline fracture of the tibia. While the Sales Team Member was not at the typical home office nor at the customer site, she was acting within the course of her employment. Therefore, this injury would be recordable and reportable as a work-related injury. On a side note, it would most likely be considered compensable as well.

There are situations where events or activities in the workplace do not qualify as work-relatedness. Table 3.1 is a list of those activities that are not required to be recorded or reported to OSHA.

Work-Relatedness for Home Injuries and Illnesses

In today's work environment, more and more employees are working remotely or from home. Home injuries or illnesses can be difficult to determine in terms of their relationship to a work-related event or condition. OSHA considers employee injuries or illnesses at home to be recordable and reportable if the injury or illness is directly related to the performance of the work rather than to the general home environment or setting. For example, if a clerical employee is working from home and trips over an open filing cabinet drawer used to store office files and injures their leg, the injury would be considered work-related. However, if the same employee is performing the same function and trips over the family pet, the injury would not be considered work-related.

Determining Recordability

Determining whether a case is to be recorded as a work-related injury or illness is an important decision for an employer to make early in the process.

TABLE 3.1

Non-work-Related Activities Exempt from OSHA Recording and Reporting (OSHA 29 CFR 1904)[1]

1904.5 (b)(2)	You are not required to record injuries and illnesses if….
(i)	At the time of the injury or illness, the employee was present in the work environment as a member of the general public rather than as an employee.
(ii)	The injury or illness involves signs or symptoms that surface at work but result solely from a non-work-related event or exposure that occurs outside the work environment.
(iii)	The injury or illness results solely from voluntary participation in a wellness program or in a medical, fitness, or recreational activity such as blood donation, physical examination, flu shot, exercise class, racquetball, or baseball.
(iv)	The injury or illness is solely the result of an employee eating, drinking, or preparing food or drink for personal consumption (whether bought on the employer's premises or brought in). For example, if the employee is injured by choking on a sandwich while in the employer's establishment, the case would not be considered work-related. **Note:** If the employee is made ill by ingesting food contaminated by workplace contaminants (such as lead) or gets food poisoning from food supplied by the employer, the case would be considered work-related.
(v)	The injury or illness is solely the result of an employee doing personal tasks (unrelated to their employment) at the establishment outside of the employee's assigned working hours.
(vi)	The injury or illness is solely the result of personal grooming, self-medication for a non-work-related condition, or is intentionally self-inflicted.
(vii)	The injury or illness is caused by a motor vehicle accident and occurs on a company parking lot or company access road while the employee is commuting to or from work.
(viii)	The illness is the common cold or flu (Note: contagious diseases such as tuberculosis, brucellosis, hepatitis A, or plague are considered work-related if the employee is infected at work).
(ix)	The illness is a mental illness. Mental illness will not be considered work-related unless the employee voluntarily provides the employer with an opinion from a physician or another licensed healthcare professional with appropriate training and experience (psychiatrist, psychologist, psychiatric nurse practitioner, etc.) stating that the employee has a mental illness that is work-related.

The general rule of thumb in the profession regarding recordability is that if there is any doubt, the injury or illness should be recorded on the appropriate form. It can always be removed later if it is eventually determined not to be work-related.

In general, an employer must consider an injury or illness to be recordable if it results in any of the following:

- Death
- Days away from work
- Restricted work or transfer to another job
- Medical treatment beyond first aid

- Loss of consciousness
- Injury or illness diagnosed by a physician or other licensed health-care professional

Note: Determining whether an injury or illness is work-related may appear simple on the surface. However, this is not always the case. In the case where an employer believes the injury or illness to be personal and not work-related, he or she must record the injury or illness on the OSHA 300 and 301 Forms until such time as it is definitively determined to be non-work-related.

The following decision tree shown in Figure 3.1 will help in determining whether a case is a recordable injury or not.

Determining New Cases

A new case is considered one in which the employee has not previously experienced a recorded injury or illness of the same type that affects the same part of the body, or the employee previously experienced a recorded injury or illness of the same type that affected the same part of the body but had recovered completely. An example of this would be an employee who had an injury that resulted in a rotator cuff tear in the right shoulder and had surgery to correct the injury. The employee completes their treatment and is released to full duty with no restrictions. The employee works three weeks and has another rotator cuff tear in the same shoulder. This would be considered a new case for recording purposes. However, if you receive recommendations from two or more physicians or other licensed healthcare professionals regarding whether the case is a continuation of the original case or a new case, the employer may remove it as a new case if the decision is based on the most authoritative recommendation.

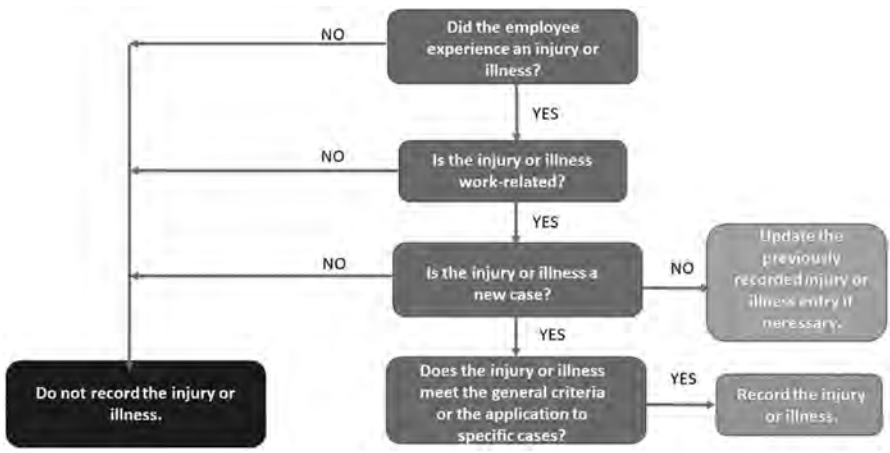


FIGURE 3.1
OSHA injury/illness recordability decision tree (29 CFR 1904.4(b)(2).[2]

Recording Criteria for Needlesticks and Sharp Injuries

Needlesticks and cuts from sharp objects that are work-related are required to be recorded on the OSHA 300 Log as injuries. Depending on the circumstances surrounding the injury, it may be necessary to protect the privacy of the employee by not entering their name on the OSHA 300 Log. The injury can be recorded simply as a "PRIVACY CASE" based on the criteria listed in 29 CFR 1904.29(b)(6) through 1904.19(b)(9). "Other potentially infected materials" is defined in the Bloodborne Pathogen standard (29 CFR 1910.1030) as human bodily fluids and other materials infected with the HIV or Hepatitis B (HBV) virus, such as laboratory cultures or tissues from experimental animals. The OSHA 300 Log must be updated if the initial cut, laceration, or needlestick, which was contaminated with another person's blood or potentially infectious material, results in death, days away from work, restricted work, or job transfer. In addition, if the injury results in the development of an infectious disease, the log must reflect the change from an injury to an illness.

If an employee is splashed or exposed to blood or other potentially infectious material without being cut or scratched, an employer is required to record the incident on the OSHA 300 Log as an illness if:

- It results in the diagnosis of a bloodborne illness, such as HIV, Hepatitis B, Hepatitis C, or
- It meets one or more of the recording criteria listed in 29 CFR 1904.7.

Recording Criteria for Cases Involving Medical Removal under OSHA Standards

An employee who has been removed from working under the medical surveillance requirements of the OSHA Standard: the employer must record the case as days away from work or restricted work activity. If the medical removal is the result of a chemical exposure, the employer must record the case on the OSHA 300 Log as "poisoning." To illustrate medical removal, the following example is provided:

- An employee working in a lead process is required to undergo periodic medical surveillance. During one of these testing periods, the employee has an elevated blood lead level and is removed from performing work-related activities involving lead. The employee can perform other non-lead-related activities. This case must be recorded on the OSHA 300 Log as restricted work.

Recording Criteria for Cases Involving Occupational Hearing Loss

Employees who have had a Standard Threshold Shift (STS) in one or both ears: it must be recorded on the OSHA 300 Log as a hearing loss. An STS is

defined in 29 CFR 1910.95(g)(10)(i) as an average of 10 decibels (dB) or more at 2000, 3000, and 4000 Hz in one or both ears as compared to the baseline audiogram. The employer may "age adjust" the current audiogram by using Tables F-1 or F-2 in 29 CFR 1910.95. However, they cannot use an age adjustment in determining whether the employee's total hearing level is 25 dB or more above audiometric zero.

Determining if a hearing loss is not work-related can be a difficult task. There are no specific rules in the OSHA Standard regarding the work-relatedness of hearing loss, so the rules established in 29 CFR 1904.5 are to be utilized. Unless there is a specific cause outside of work, such as an injury or specific illness that caused the hearing loss, it is presumed to be work-related.

Reporting Fatalities, Injuries, and Illness Information to the Government

OSHA requires an employer to notify them within 8 hours after the death of any employee from a work-related incident or multiple hospitalizations of employees. In addition, the employer must report in-patient hospitalizations of one or more employees, or an employee's amputation or an employee's loss of an eye as a result of a work-related incident within 24 h. *A work-related fatality or in-patient hospitalization caused by a heart attack should be reported as well. An employee who is on an employer's work site and dies from a heart attack is initially considered a work-related fatality. While the heart attack may eventually be presumed to be personal in nature, it must be initially reported to OSHA*. This report can be done by one of the following methods:

- By telephone or in person to the OSHA Area Office that is nearest to the site of the incident.
- By telephone to OSHA toll-free central telephone number, 1-800-321-OSHA (1-800-321-6742).
- By electronic submission using the reporting application located on OSHA's public website at www.osha.gov/report.

To report the injury, the employer should have the following information available:

- The establishment name
- The location of the work-related incident
- The time of the work-related incident
- The type of reportable event (i.e., fatality, in-patient hospitalization, amputation, or loss of an eye)

- The number of employees who suffered a fatality, in-patient hospitalization, amputation, or loss of an eye
- The names of the employees who suffered a fatality, in-patient hospitalization, amputation, or loss of an eye
- Your contact person and his or her telephone number
- A brief description of the work-related incident

One exception to this is a fatality or hospitalizations resulting from a motor vehicle accident occurring on a public road. These do not have to be reported.

Record Keeping

OSHA 300, 300A, and 301 Forms (29 CFR 1904.29)*3*

Employers must use OSHA 300, 300A, and 301 forms, or equivalent forms, for recordable injuries and illnesses. The OSHA 300 form is called the Log of Work-Related Injuries and Illnesses, the 300A form is the Summary of Work-Related Injuries and Illnesses, and the OSHA 301 form is called the Injury and Illness Incident Report.

How Quickly Must Each Injury or Illness Be Recorded?

An employer must enter each recordable injury or illness on the 300 and 301 incident report within ***7 calendar days*** of receiving information that a recordable injury or illness has occurred.

How Do "Privacy Cases" Listed on the Forms?

The following cases are considered to be privacy cases, and therefore the employee's name is not entered on the OSHA 300 form. Instead, enter "PRIVACY CASE" in place of the employee's name.

- An injury or illness to an intimate body part or the reproductive system
- An injury or illness resulting from a sexual assault
- Mental illnesses
- HIV infection, hepatitis, or tuberculosis
- Needle stick injuries and cuts from sharp objects that are contaminated with another person's blood or other potentially infectious materials
- Other illnesses if the employee voluntarily requests that his or her name not be entered on the log

Annual Summary

An annual summary is created on the OSHA 300 Log and is certified by a company owner or designated representative. The OSHA 300A form is signed by a company owner or designated representative and posted in a conspicuous location no later than 1 ***February*** of the year following the year covered by the records. The OSHA 300A form shall remain posted until 30 ***April*** of the year following the year covered by the records. OSHA 300 logs (and separate privacy case files, if required) for a period of 5 years following the end of the calendar year that these records cover.

Providing Records to Government Representatives

When an authorized government representative asks for the records you keep under 1904, you must provide copies of the records within 4 business hours. Authorized government representatives under this standard include:

- A representative of the Secretary of Labor
- A representative of the Secretary of Health and Human Services
- A representative of a State agency responsible for administering a state plan approved under the Act

Calculating Total Case Incident Rates (TCIR)

To calculate a company's TCIR, use the following equation:

$$\text{TCIR} = \frac{\text{No. of Injury or Illness Case} \times 200{,}000}{\text{Total Number of Hours Worked}}$$

Example

A company has two recordable injury cases and 1 Days Away or Restricted Case for a total of three cases. The company has worked a total of 278,942 h for the year. Calculate the TCIR for this company.

$$\text{TCIR} = \frac{3 \times 200{,}000}{278{,}942\,\text{hours}}$$

$$\text{TCIR} = \frac{600{,}000}{278{,}942}$$

$$\text{TCIR} = 2.15$$

The company's total case incident rate for the year is 2.15. This rate can be compared to the Bureau of Labor and Statistics' average rating for your particular Standard Industry Code (SIC) category. The constant of 200,000 is based on 100 employees working 2000 h per year. Therefore, this rate states that for every 100 employees, 2.15 of them have sustained an injury or illness as a result of a work-related accident.

Calculating Days Away, Restricted, or Transfer (DART) Rates

To calculate the DART rate, use only those injury cases (included in the TCIR) that resulted in days away, restricted, or transfer from the job. The equation is as follows:

$$\text{DART} = \frac{\text{No. of DART Cases} \times 200{,}000}{\text{Total Number of Hours Worked}}$$

Example:

As in the previous example, use one DART case and 278,942 total hours work to calculate the DART Rate.

$$\text{DART} = \frac{1\text{case} \times 200{,}000}{278{,}942}$$

$$\text{DART} = \frac{200{,}000}{278{,}942}$$

$$\text{DART} = 0.72$$

Calculating Severity Rates

To calculate severity rates, use the following equation:

$$\text{Severity Rate} = \frac{\text{No. of Lost Work Days} \times 200{,}000}{\text{Total Number of Hours Worked}}$$

Example:

Company XYZ had two recordable injuries, with one of them resulting in 52 days of lost time. The total number of hours worked was 278,942 h.

$$\text{Severity Rate} = \frac{52 \times 200{,}000}{278{,}942}$$

$$\text{Severity Rate} = \frac{10{,}400{,}000}{278{,}942}$$

$$\text{Severity Rate} = 37.28$$

Retention and Updating

The OSHA 300 Log, the Privacy Case List, the Annual Summary, and the OSHA 301 Incident Report must be maintained by the organization for 5 years following the end of the calendar year that these records cover. If during this 5-year period, there is a change in the status of a particular case, such as a case from August of 1 year that was a recordable injury becoming a lost-time injury case in January of the following year. In this example, the previous year's OSHA 300 Log must be updated to reflect the change. It is not necessary to change or update the annual summary.

Key Information to Remember on Reporting and Recording Occupational Injuries and Illnesses

1. Work-related fatalities must be reported to OSHA within 8 h of the fatality.
2. In-patient hospitalizations of one or more persons from a work-related injury or illness, amputation, or loss of an eye must be reported to OSHA within 24 h.
3. Employers with 10 or more employees are required to maintain records of occupational injuries.
4. OSHA defines the work environment as "the establishment or other locations where one or more employees are working or are present as a condition of their employment."
5. OSHA considers employee injuries or illnesses at home to be recordable and reportable if the injury or illness is directly related to the performance of the work rather than to the general home environment or setting.

6. A new case is considered one in which the employee has not previously experienced a recorded injury or illness of the same type that affects the same part of the body, or the employee previously experienced a recorded injury or illness of the same type that affected the same part of the body but had recovered completely.
7. Needlesticks and cuts from sharp objects that are work-related are required to be recorded on the OSHA 300 Log as injuries.
8. An employee who has been removed from working under the medical surveillance requirements of the OSHA Standard: the employer must record the case as days away from work or restricted work activity.
9. Employees who have had a Standard Threshold Shift (STS) in one or both ears: it must be recorded on the OSHA 300 Log as a hearing loss.
10. An employer must enter each recordable injury or illness on the 300 and 301 incident report within ***7 calendar days*** of receiving information that a recordable injury or illness has occurred.
11. A work-related recordable injury must be recorded on the OSHA 300 and 301 forms within 7 working days of receiving notification of the injury or illness.
12. When an authorized government representative asks for records required in 29 CFR 1904, an employer must provide copies within 4 business hours.

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4

Regulations

During the course of this chapter, the basic requirements of the more common regulations that the safety professional encounters on a routine basis will be discussed. This chapter is not intended as a substitute for reading the complete regulation for specific details. It is intended only as a summary of the standards. However, the information provided will provide a good basic understanding and familiarize the examination candidate sufficiently enough to answer questions on the Associate Safety Professional/Certified Safety Professional examinations. This chapter will cover the following topics: General Duty Clause, Occupational Safety and Health Administration (OSHA) Record Keeping, Hazardous Communication Standard, Bloodborne Pathogens, Lockout/Tagout, Confined Space Entry, Respiratory Protection, Powered Industrial Trucks and Aerial Lifts, Personal Protective Equipment (PPE), and Fall Protection.

Occupational Safety and Health Act

The Occupational Safety and Health Act (Public Law 91-596) was passed into law on December 29, 1970. It may also be referred to as the Williams-Steiger Occupational Safety and Health Act of 1970. The purpose of the law is

> to assure safe and healthful working conditions for working men and women; by authorizing enforcement of the standards developed under the Act; by assisting and encouraging the States in their efforts to assure safe and healthful working condition; by providing for research, information, education, and training in the field of occupational safety and health; and for other purposes.

The OSHA was created within the Department of Labor. The primary responsibilities assigned to OSHA under the Act are as follows:

- Encourage employers and employees to reduce workplace hazards and to implement new or improve existing safety and health standards.
- Provide for research in occupational safety and health and develop innovative ways of dealing with occupational safety and health problems.

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- Establish "separate but dependent responsibilities and rights" for employers and employees for the achievement of better safety and health conditions.
- Maintain a reporting and record-keeping system to monitor job-related injuries and illnesses; establish training programs to increase the number of competent occupational safety and health personnel.
- Develop mandatory job safety and health standards and enforce them effectively.

Who Is Covered under the Occupational Safety and Health Act?

Basically, all private sector employers with one or more workers in all 50 states and US territories are governed under the OSH Act. OSHA regulations do not apply to all employers in the public sector (municipal, county, state, or federal government agencies), self-employed individuals, family members operating a farm, or domestic household workers.

Horizontal and Vertical Standards

Standards are referred to as either horizontal or vertical. *Horizontal standards* are those standards that apply to all industries and employers. For example, fire prevention and protection standards are horizontal standards. *Vertical standards* are those standards that apply only to particular industries and employers. Standards that apply only to the construction industry are an example of vertical standards.

General Duty Clause

Each standard promulgated by OSHA cannot cover every specific detail. Therefore, OSHA has implemented a "general duty clause" into the regulations. The general duty clause states that an employer shall furnish "a place of employment which is free from recognized hazards that are causing or are likely to cause death or serious physical harm to its employees." Where there is no specific standard, OSHA will use the general duty clause for the issuance of citations and fines.

The general duty clause can be found in Section 5 (a)(1) of the Occupational Safety and Health Act of 1970.

Employer Rights and Responsibilities

Besides meeting the intent of the general duty clause, the employer must

- Examine workplace conditions to make sure they comply with applicable standards
- Minimize or reduce hazards
- Use color codes, posters, labels, or signs when needed to warn employees of potential hazards
- Provide training required by applicable OSHA standards
- Keep OSHA-required records
- Provide access to employee medical records and exposure records to employees or their authorized representatives

Employee Rights and Responsibilities

OSHA requires workers to comply with all safety and health standards that apply to their actions on the job. Employees should

- Read the OSHA poster
- Follow the employer's safety and health rules and wear or use all required gear and equipment
- Follow safe work practices for your job, as directed by your employer
- Report hazardous conditions to a supervisor or safety committee
- Report hazardous conditions to OSHA if employers do not fix them
- Expect safety and health on the job without fear of reprisal

Communications and Correspondence with OSHA

There are two trains of thought among safety professionals when communicating and dealing with OSHA. The first train of thought is the belief that OSHA is the enemy and any communication or correspondence with them will result negatively for the company. The second thought is that OSHA has a purpose to protect the health and safety of employees and serve as a valuable resource and partner for American businesses. Most OSHA personnel are experienced and knowledgeable professionals and can serve as a useful resource in making decisions and often have ideas that you may not have

thought of when trying to solve a particular problem within your facility or operation. With this being said, I would urge caution in providing information on an official basis. The safety professional must remember that a large portion of OSHA's responsibility lies in enforcing the regulations. Therefore, information provided to them can be used to levy penalties against your organization. When confronted on an official basis with a potential citation or penalty, it is best to provide only those specific documents that are requested. This, of course, is only a personal opinion, based on my experiences.

OSHA Inspections and Process

Whenever an OSHA inspection occurs, the employer must

- Be advised by the compliance officer of the reason for the inspection
- Require identification of the OSHA compliance officer
- Accompany the compliance officer on the inspection
- Be assured of the confidentiality of any trade secrets observed by an OSHA compliance officer during an inspection

Under the OSH Act, OSHA is authorized to conduct workplace inspections during normal operating hours. Inspections are based on the following priorities:

- Imminent danger situations
- Catastrophes and fatal accidents
- Employee complaints
- Programmed high-hazard inspections
- Follow-up inspections

The inspection process starts even before the compliance officer visits your site. The compliance officer will prepare himself or herself by becoming familiar with your particular industry and business through research. He or she will be familiar with the potential hazards and processes involved with your particular business. Once on site, the compliance officer begins by presenting his or her credentials. *Note: The compliance officer has the right, under the law, for timely admission to the facility. Any unnecessary delay or refusal of admittance may prompt the compliance officer to obtain a warrant for inspection purposes.* Once the authorized credentials have been presented, the compliance officer will hold an opening conference. In the opening conference, the compliance officer will explain the purpose of the visit, how your particular facility was selected for inspection, the scope of the inspection, and the

standards that will apply. The compliance officer will ask the employer to select an employer representative to accompany him or her on the inspection. The compliance officer also allows an authorized employee representative the opportunity to attend the opening conference and accompany the compliance officer during the inspection. The Act does not require an employee representative to accompany the compliance officer. After the opening conference, the compliance officer conducts a walkthrough inspection of the facility. During the walkthrough inspection, the compliance officer determines which route to take and which employees he or she will talk with. The compliance officer may review records, collect air samples, measure noise readings, or photograph and videotape certain areas. Once the compliance officer has completed the walkthrough inspection, he or she will hold a closing conference. During the closing conference, the compliance officer gives the employer and all other interested parties a copy of the Employer Rights and Responsibilities Following an OSHA Inspection (OSHA 3000) for their review and discussion. The compliance officer discusses with the employer all unsafe or unhealthful conditions observed during the inspection and indicates the violations for which he or she may recommend a citation and a proposed penalty. At this time, the compliance officer will also inform the employer of the appeal process.

OSHA Citations

After the compliance officer files his or her report with the Area Director, it is the Area Director who determines whether he or she will issue a citation or propose penalties. The Area Director will send all citations via certified mail. Once the employer has received the citation, they must post the citation *for 3* days or until the violation has been abated, *whichever is longer.*

OSHA Citation Penalties

The categories of violations that are cited and the penalties that may be proposed are as follows:

Other-than-serious violation: A violation that has a direct relationship to job safety and health but probably would not cause death or serious physical harm. OSHA may assess a penalty of $16,131 for each violation. The agency may adjust a penalty for an other-than-serious violation downward by as much as 95%, depending on the employer's good faith, history of previous violations, and size of business.

Serious violation: A violation where there is a substantial probability that death or serious physical harm could result. OSHA assesses the penalty for a serious violation of $16,131 for each violation. OSHA may adjust a penalty for a serious violation downward on the basis of the employer's good faith, history of previous violations, and size of business.

Willful violation: A violation that the employer intentionally and knowingly commits. The employer is aware that a hazardous condition exists, knows that the condition violates a standard or other obligation of the Act, and makes no reasonable effort to eliminate it. OSHA may propose penalties of $161,323 for each willful violation.

Repeated violation: A violation of any standard, regulation, rule, or order where, upon reinspection, a substantially similar violation is found, and the original citation has become a final order. Violations can bring a fine of $161,323 for each repeated violation.

Failure to abate violation: Failure to correct a prior violation may bring a civil penalty of $16,131 for each day that the violation continues beyond the prescribed abatement date.

Potential other penalties: Additional violations for which OSHA may issue citations and proposed penalties are as follows:

- Falsifying records, reports, or applications can, upon conviction, bring a criminal fine of $10,000 or up to 6 months in jail, or both.
- Violating posting requirements may bring a civil penalty of $16,131.
- Assaulting a compliance officer or otherwise resisting, opposing, intimidating, or interfering with a compliance officer in the performance of his or her duties is a criminal offense and is subject to a fine of not more than $5000 and imprisonment for not more than 3 years.

Note 1: Citations and penalty procedures may differ slightly in states with their own occupational safety and health programs.

Note 2: In the future, the Department of Labor is required to adjust minimum OSHA penalties for inflation by January 15 of each new year.

Adjustment of Penalties for Good Faith

OSHA has a policy of reducing penalties for small employers and those acting in good faith. For serious violations, OSHA may also reduce the proposed penalty based on the gravity of the alleged violation. No good faith adjustment will be made for alleged willful violations (https://www.osha.gov/OshDoc/data_General_Facts/factsheet-inspections.pdf).

Appeals

Once a citation or non-citation is issued, an employee or an employer may appeal the decision by the Area Director. The appeals process is different for the employer than it is for the employee.

Employee Appeals

If an employee complaint initiates an inspection, the employee or authorized employee representative may request an informal review of any decision not to issue a citation. Employees may not contest citations, amendments to citations, proposed penalties, or lack of penalties. They may, however, contest the time allowed for abatement of a hazardous condition. They also may request an employer's "Petition for Modification of Abatement," which requests an extension of the proposed abatement period. Employees must contest the petition within 10 working days of its posting or within 10 working days after an authorized employee receives a copy. Employees may request an informal conference with OSHA to discuss any issues raised by an inspection, citation, notice of proposed penalty, or employer's notice of intention to contest.

Employer Appeals

Within 15 working days of receiving a citation, an employer who wishes to contest must submit a written objection to OSHA. The OSHA Area Director forwards the objection to the Occupational Safety and Health Review Commission (OSHRC), which operates independently of OSHA. The OSHRC is a commission of three-member administrative law judges appointed by the President of the United States, with the consent of congress. Each judge appointed serves a term of 6 years. Initial appointments were 2 years for the first judge, 4 years for the second judge, and 6 years for the third judge. Each succeeding judge is appointed for a term of 6 years. This provides some administrative consistency within the commission.

When issued a citation and notice of the proposed penalty, an employer may request an informal meeting with OSHA's Area Director to discuss the case. OSHA encourages employers to have informal conferences with the Area Director if the employer has issues arising from the inspection that he or she wishes to discuss or provide additional information. The Area Director is authorized to enter into settlement agreements that revise citations and penalties to avoid prolonged legal disputes and result in speedier hazard abatement. (Alleged violations contested before OSHRC do not need to be corrected until the contest is ruled upon by OSHRC.)

Petition for Modification of Abatement

After receiving a citation, the employer must correct the cited hazard by the abatement date unless he or she contests the citation or abatement date. Factors beyond the employer's control, however, may prevent the completion of corrections by that date. In such a situation, the employer who has made a good-faith effort to comply may file a petition to modify the abatement date.

The written petition must specify the steps taken to achieve compliance, the additional time needed to comply, the reasons additional time is needed, and interim steps taken to safeguard employees against the cited hazard during the intervening period. The employer must certify that he or she posted a copy of the petition in a conspicuous place at or near each place where a violation occurred and that the employee representative received a copy of the petition.

Notice of Contest

If the employer decides to contest either the citation, the abatement period, or the proposed penalty, he or she has *15 working days* from the time the citation and proposed penalty are received to notify the OSHA Area Director in writing. Failure to do so results in the citation and proposed penalty becoming a final order of the OSHRC without further appeal. An orally expressed disagreement will not suffice. This written notification is called a "Notice of Contest."

Although there is no specific format for the Notice of Contest, it must clearly identify the employer's basis for filing—the citation, notice of proposed penalty, abatement period, or notification of failure to correct violations.

The employer must give a copy of the Notice of Contest to the employees' authorized representative. If any affected employees are not represented by a recognized bargaining agent, the employer must post a copy of the notice in a prominent location in the workplace or give it personally to each unrepresented employee.

Review Procedure

If the employer files a written Notice of Contest within the required 15 working days, the OSHA Area Director forwards the case to OSHRC. The commission is an independent agency not associated with OSHA or the Department of Labor. The commission assigns the case to an administrative law judge.

OSHRC may schedule a hearing at a public place near the employer's workplace. The employer and the employee have the right to participate in the hearing; the OSHRC does not require them to be represented by attorneys. Once the administrative law judge has ruled, any party to the case may request a further review by OSHRC. Any of the three OSHRC commissioners may also, at his or her own motion, bring a case before the commission for review. Employers and other parties may appeal commission ruling to the appropriate US Court of Appeals.

- Note: The sections included above from OSHA Inspection Process through Review Procedure were taken from an OSHA web pamphlet (OSHA 2098 Rev. 2002) that requires no copyright permissions because it is in the public domain. However, it is the author's preference to give credit for work that is not his own.

States with their own occupational safety and health programs have a state system for review and appeal of citations, penalties, and abatement periods. The procedures are generally similar to Federal OSHAs, but a state review board or equivalent authority hears cases.

Hazard Communication Standard (29 CFR 1910.1200)

- Note: This standard has undergone tremendous changes since the initial publication of this book. Therefore, at the end of this chapter, I have elected to republish OSHA's Comparison of Hazard Communication Requirements between OSHA Hazard Communication Standard 29 CFR 1910.1200 (HCS) and Globally Harmonized System (GHS).

Purpose

This standard is still known as the Hazard Communication Standard but is unofficially known as Globally Harmonized System (GHS). However, it has undergone significant changes in the last few years. The purpose of this section is to ensure that the hazards of all chemicals produced or imported are classified and that information concerning the classified hazards is transmitted to employers and employees. The requirements of this section are intended to be consistent with the provisions of the *United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS), Revision* 3. The transmittal of information is to be accomplished by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, safety data sheets (SDSs), and employee training.

Scope and Application

This standard requires chemical manufacturers or importers to classify the hazards of chemicals that they produce or import and all employers to provide information to their employees about the hazardous chemicals to which they are exposed, by means of a hazard communication program, labels and other forms of warning, SDSs, and information and training. In addition,

this standard requires distributors to transmit the required information to employers. (Employers who do not produce or import chemicals need only focus on those parts of the rule that deal with establishing a workplace program and communicating information to their workers.)

This standard applies to any chemical that is known to be present in the workplace in such a manner that employees may be exposed under normal conditions of use or in a foreseeable emergency.

Written Hazard Communication Standard

Employers are required to develop, implement, and maintain at each workplace a written hazard communication program that at least describes how the program will be managed and operated, including the requirements for labeling and other forms of warning, SDSs, and employee information and training, and how these requirements will be met, which also includes the following:

- A list of the hazardous chemicals known to be present using a product identifier that is referenced on the appropriate SDS (the list may be compiled for the workplace as a whole or for individual work areas)
- The methods the employer will use to inform employees of the hazards of nonroutine tasks (e.g., the cleaning of reactor vessels) and the hazards associated with chemicals contained in unlabeled pipes in their work areas
- *Multi-employer workplaces.* Employers who produce, use, or store hazardous chemicals at a workplace in such a way that the employees of other employers may be exposed shall additionally ensure that the hazard communication programs developed and implemented are transmitted to those employees and employers.

Label and Other Forms of Warning

The chemical manufacturer, importer, or distributor shall ensure that each container of hazardous chemicals leaving the workplace is labeled, tagged, or marked. Hazards not otherwise classified do not have to be addressed on the container. Where the chemical manufacturer or importer is required to label, tag, or mark, the following shall be provided:

- Product identifier
- Signal word
- Hazard statement(s)
- Pictogram(s)
- Precautionary statement(s)

- Name, address, and telephone number of the chemical manufacturer or other responsible party

Safety Data Sheets

Chemical manufacturers and importers shall obtain or develop an SDS for each hazardous chemical they produce or import. Employers shall have an SDS in the workplace for each hazardous chemical that they use. The chemical manufacturer or importer preparing the SDS shall ensure that it is in English (although the employer may maintain copies in other languages as well) and includes at least the following section numbers and headings, and associated information under each heading, in the order listed below: (See Appendix D to 29 CFR 1910.1200—Safety Data Sheets, for the specific content of each section of the SDS.)

- Section 1: Identification
- Section 2: Hazard identification
- Section 3: Composition/information on ingredients
- Section 4: First-aid measures
- Section 5: Fire-fighting measures
- Section 6: Accidental release measures
- Section 7: Handling and storage
- Section 8: Exposure controls/personal protection
- Section 9: Physical and chemical properties
- Section 10: Stability and reactivity information
- Section 11: Toxicological information

Note 1: To be consistent with the GHS, an SDS must also include the following headings in this order:

- Section 12: Ecological information
- Section 13: Disposal considerations
- Section 14: Transport information
- Section 15: Regulatory information

Employee Information and Training

Employee training and information is at the core of this standard. Employers shall provide employees with effective information and training on hazardous chemicals in their work area at the time of their initial assignment and whenever a new physical or health hazard that the employees have not

previously been trained about is introduced into their work area. Information and training may be designed to cover categories of hazards or specific chemicals. Chemical-specific information must always be available through labels and material SDSs.

Training

Employee training shall include at least the following information:

- Methods and observations that may be used to detect the presence or release of hazardous chemicals in the work area
- The physical and health hazards of the chemicals in the work area
- The measure employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals
- The details of the hazard communication program developed by the employer, including the explanation of the labeling system and the material SDS, and how employees can obtain and use the appropriate hazard information

Blood Borne Pathogens Standard (29 CFR 1910.1030)

Scope, Application, and Definitions

The information provided in this standard applies to all occupation exposure to blood or other potentially infectious materials present in the workplace. Definitions within this standard are as follows:

Blood means human blood, human blood components, and products made from human blood.

Bloodborne pathogens means pathogenic microorganisms that are present in human blood and cause disease in humans. These pathogens include, but are not limited to, hepatitis B virus (HBV) and human immunodeficiency virus (HIV).

Other potentially infectious materials means the following human body fluids: semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, saliva in dental procedures, any body fluid that is visibly contaminated with blood, and all body fluids in situations where it is difficult or impossible to differentiate between body fluids or any unfixed tissue or organ from a human.

Exposure Control Plan

Each employer having an employee (or employees) with occupational exposure or potential exposure to bloodborne pathogens shall establish a

written Exposure Control Plan designed to eliminate or minimize employee exposure. The Exposure Control Plan shall contain at least the following information:

- The exposure determination
- The schedule and method of implementation for Methods of Compliance, HIV and HBV Research Laboratories and Production Facilities, Hepatitis B Vaccination and Postexposure Evaluation and Follow-up, Communication of Hazards to Employees, and Record Keeping

The Exposure Control Plan shall be reviewed and updated at least annually and whenever necessary to reflect new or modified tasks and procedures that affect occupational exposure and to reflect new or revised employee positions with occupational exposure.

Hepatitis B Vaccination and Postexposure Follow-Up

The employer shall make available the hepatitis B vaccine and vaccination series to all employees who have occupational exposure and postexposure evaluation and follow-up to all employees who have had an exposure incident. Should an employee refuse to take the hepatitis B vaccine, the employer is required to obtain a written statement of his or her refusal.

Communication of Hazards

Labels and signs shall be affixed to containers of regulated waste, refrigerators and freezers containing blood or other potentially infectious materials, and other containers used to store, transport, or ship blood or other potentially infectious materials.

Record Keeping

Medical Records

The employer shall establish and maintain an accurate record for each employee with occupational exposure. This record shall include the following:

- The name and social security number of the employee
- A copy of the employee's hepatitis B vaccination status including the dates of all the hepatitis B vaccinations and any medical records relative to the employee's ability to receive vaccination
- A copy of all results of examinations, medical testing, and follow-up procedures

- The employer's copy of the healthcare professional's written opinion
- A copy of the information provided to the healthcare professional

The employer shall ensure that employee medical records and information are maintained in the strictest of confidence. The information contained in the medical records may not be disclosed or reported without the employee's express written consent, except as required by this standard. The employer shall maintain the records required under this standard for at least the duration of employment plus 30 years.

Training Records

Training records shall include the following information:

- The dates of the training sessions
- The contents or a summary of the training sessions
- The names and qualification of persons conducting the training
- The names and job titles of all persons attending the training sessions

Training records shall be maintained for 3 years from the date on which the training occurred.

Control of Hazardous Energy Standard (29 CFR 1910.147)

Scope, Application, and Purpose

This standard covers the servicing and maintenance of machines and equipment in which the unexpected energization or start-up of the machines or equipment or the release of stored energy could cause injury to employees. This standard establishes minimum performance requirements for the control of such hazardous energy. This standard applies to the control of energy during servicing or maintenance of machines and equipment.

Definitions

Affected employee: An employee whose job requires him or her to operate or use a machine or equipment on which servicing or maintenance is being performed under lockout or tagout, or whose job requires him or her to work in an area in which such servicing or maintenance is being performed.

Authorized employee: A person who locks or tags out machines or equipment in order to perform servicing or maintenance on a machine or equipment. An affected employee becomes an authorized employee when that employee's duties include performing servicing or maintenance covered by this standard.

Capable of being locked out: An energy-isolating device capable of being locked out if it has a hasp or other means of attachment to which a lock can be affixed or it has a locking mechanism built into it. Other energy- isolating devices are capable of being locked out, if lockout can be achieved without the need to dismantle, rebuild, or replace the energy- isolating device or permanently alter its energy control capability.

Energized: Connected to an energy source or containing a residual or stored energy.

Energy-isolating device: A mechanical device that physically prevents the transmission or release of energy, including but not limited to the following: a manually operated electrical circuit breaker; a disconnect switch; a manually operated switch by which the conductors of a circuit can be disconnected for all ungrounded supply conductors, and, in addition, no pole can be operated independently; a line valve; a block; and any similar device used to block or isolate energy. Push buttons, selector switches, and other control circuit-type devices are not energy-isolating devices.

Energy source: Any source of electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other energy.

Hot tap: A procedure used in the repair, maintenance, and services activities that involves welding on a piece of equipment under pressure, in order to install connections or appurtenances.

Lockout: The placement of a lockout device on an energy-isolating device, in accordance with established procedure, ensuring that the energy-isolating device and the equipment being controlled cannot be operated until the lockout device is removed.

Lockout device: A device that utilizes a positive means, such as a lock, either key or combination type, to hold an energy-isolating device in a safe position and prevent the energizing of a machine or equipment.

Normal production operations: The utilization of a machine or equipment to perform its intended production function.

Servicing or maintenance: Workplace activities such as constructing, installing, setting up, adjusting, inspecting, modifying, and maintaining or servicing machines or equipment.

Setting up: Any work performed to prepare a machine or equipment to perform its normal production operation.

Tagout: The placement of a tagout device on an energy-isolating device, in accordance with established procedure, to indicate that the energy-isolating device and the equipment being controlled may not be operated until the tagout device is removed.

Tagout device: A prominent warning device, such as a tag and a means of attachment, which can be securely fastened to an energy-isolating device in accordance with established procedure, to indicate that the energy-isolating device and the equipment being controlled may not be operated until the tagout device is removed.

Energy Control Program

The employer shall establish a program consisting of energy control procedures, employee training, and periodic inspections to ensure that before any employee performs any servicing or maintenance on a machine or equipment where the unexpected energizing, start-up, or release of stored energy could occur and cause injury, the machine or equipment shall be isolated from the energy source and rendered inoperative.

Periodic Inspection

The employer shall conduct a periodic inspection of the energy control procedure at least annually to ensure that the procedure and the requirements of this standard are being followed. The periodic inspection shall be performed by an authorized employee other than the one(s) utilizing the energy control procedure being inspected. The periodic inspection shall be conducted to correct any deviations or inadequacies identified. The employer shall certify that the periodic inspections have been performed. The certification shall identify the machine or equipment on which the energy control procedure was being utilized, the date of the inspection, the employees included in the inspection, and the person performing the inspection.

Training and Communication

The employer shall provide training to ensure that the purpose and function of the energy control program are understood by employees and that the knowledge and skills required for the safe application, usage, and removal of the energy controls are acquired by employees. The training shall include the following:

- Recognition of applicable hazardous energy sources, the type and magnitude of the energy available in the workplace, and the methods and means necessary for energy isolation and control
- Purpose and use of the energy control procedure
- Prohibition relating to attempts to restart or reenergize machines or equipment that are locked or tagged out

Retraining shall be provided for all authorized and affected employees whenever there is a change in their job assignments, a change in machines, equipment, or processes that present a new hazard, or when there is a change in the energy control procedures. Additional retraining shall also be conducted whenever a periodic inspection reveals inadequacies in the program or procedures. The employer shall certify that employee training has been accomplished and is being kept up to date. The certification shall contain each employee's name and dates of training.

Confined Space Entry Standard (29 CFR 1910.146)

Scope and Application

This standard contains requirements for practices and procedures to protect employees in general industry from the hazards of entry into permit-required confined spaces. This standard does not apply to agriculture, construction, or shipyard employment.

Definitions

Acceptable entry conditions means the conditions that must exist in a permit space to allow entry and to ensure that employees involved with a permit-required confined space entry can safely enter into and work within the space.

Attendant means an individual stationed outside one or more permit spaces who monitors the authorized entrants and who performs all attendant's duties assigned in the employer's permit space program.

Authorized entrant means an employee who is authorized by the employer to enter a permit space.

Confined space means a space that (1) is large enough and so configured that an employee can bodily enter and perform assigned work, (2) has limited or restricted means for entry or exit, and (3) is not designed for continuous employee occupancy.

Engulfment means the surrounding and effective capture of a person by a liquid or finely divided (flowable) solid substance that can be aspirated to cause death by filling or plugging the respiratory system or than can exert enough force on the body to cause death by strangulation, constriction, or crushing.

Entry means the action by which a person passes through an opening into a permit-required confined space.

Entry permit means the written or printed document that is provided by the employer to allow and control entry into a permit space and that contains the information required in the standard.

Entry supervisor means the person responsible for determining if acceptable entry conditions are present at a permit space where entry is planned, for authorizing entry and overseeing entry operations, and for terminating entry as required in the standard.

Hazardous atmosphere means an atmosphere that may expose employees to the risk of death, incapacitation, impairment of ability to selfrescue, injury, or acute illness.

Immediately dangerous to life or health means any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individual's ability to escape unaided from a permit space.

Isolation means the process by which a permit space is removed from service and completely protected against the release of energy and material into the space.

Oxygen-deficient atmosphere means an atmosphere containing less than 19.5% oxygen by volume.

Oxygen-enriched atmosphere means an atmosphere containing more than 23.5% oxygen by volume.

Permit-required confined space means a confined space that has one or more of the following characteristics: (1) contains or has a potential to contain a hazardous atmosphere, (2) contains a material that has the potential for engulfing an entrant, (3) has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section, or (4) contains any other recognized serious safety or health hazard.

Rescue service means the personnel designated to rescue employees from permit spaces.

General Requirements

The employer shall evaluate the workplace to determine if any spaces are permit-required confined spaces. If the workplace contains permit spaces, the employer shall inform exposed employees by posting danger signs, or by any other equally effective means, of the existence and location of and the danger posed by the permit spaces.

Confined Space Entry Program

If the employer decides that its employees will enter permit spaces, the employer shall develop and implement a written permit space program that complies with this standard. The written program shall be available for inspection by employees and their authorized representatives.

Under the confined space entry program, the employer shall

- Implement the measures necessary to prevent unauthorized entry
- Identify and evaluate the hazards of permit spaces before the employee enters them
- Develop and implement the means, procedures, and practices necessary for safe permit space entry operations

Entry Permits

The entry permit that documents compliance with this standard and authorizes entry to a permit space shall include the following:

- The permit space to be entered
- Purpose of the entry
- Date and the authorized duration of the entry permit
- Authorized entrants by name
- Attendant name
- Entry supervisor (by name)
- Measures to isolate the permit space and to eliminate or control permit space hazards before entry

Employees must have the opportunity to observe the monitoring under this standard.

Training

The employer shall provide training so that all employees whose work is regulated by this standard acquire the understanding, knowledge, and skills necessary for the safe performance of their duties. Training shall be provided to each affected employee before the employee is first assigned duties under this standard. Whenever there is a change in assigned duties, the employer determines that there is a discrepancy in the program, or there is a change in permit space operations that present a hazard about which an employee has not previously been trained, and thus additional training is required. The employer shall certify that the training required has been accomplished. The certification shall contain each employee's name, the signatures or initial of the trainers, and the dates of training. The certification shall be available for inspection by employees and their authorized representatives.

Personal Protective Equipment (29 CFR 1910.132)

Application

Protective equipment covered in this standard includes PPE for eyes, face, head, and extremities; protective clothing; respiratory devices; and protective

shield and barriers, which shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation, or physical contact.

- Note: OSHA's Final PPE Rule, which was effective February 13, 2008, requires employers to provide PPE, at no cost to the employees. The Final Rule does not require an employer to provide normal safety boots or shoes but does require the employer to provide specialty boots.

Employee-Owned Equipment

Where employees provide their own protective equipment (of their own choice), the employer shall be responsible for assuring its adequacy, including proper maintenance and sanitation of such equipment.

Hazard Assessment and Equipment Selection

The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of PPE. If such hazards are present, or likely to be present, the employer shall (a) select and have each affected employee use the types of PPE that will protect the affected employee from the hazards identified in the hazard assessment, (b) communicate selection decisions to each affected employee, and (c) select PPE that properly fits each affected employee. The employer shall verify that the required workplace hazard assessment has been performed through a written certification that identifies the workplace evaluated; the person certifying that the evaluation has been performed; the date(s) of the hazard assessment; and, which determines the document as a certification of the hazard assessment.

Training

The employer shall provide training to each employee who is required under this standard to use PPE. Each employee shall be trained to know at least the following:

- When PPE is necessary
- What PPE is necessary
- How to properly don, doff, adjust, and wear PPE
- Limitations of the PPE
- Proper care, maintenance and useful life, and disposal of the PPE

Each affected employee shall demonstrate an understanding of the training and the ability to use PPE properly, before being allowed to perform work requiring the use of PPE. When the employer has reason to believe that any affected employee who has already been trained does not have the understanding and skill required, the employer shall retrain each such employee.

Respiratory Protection Standard (29 CFR 1910.134)

Purpose

The purpose of the Respiratory Protection Standard is to control those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors. This shall be accomplished as far as feasible by accepted engineering control measures. When effective engineering control measures are not feasible, or while they are being instituted, appropriate respirators shall be used.

Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee. The employer shall provide the respirators that are applicable and suitable for the purpose intended. The employer shall be responsible for the establishment and maintenance of a respiratory protection program, which shall include the requirements of this standard.

Definitions

Air-purifying respirator means a respirator with an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air-purifying element.

Assigned protection factor means the protection factor assigned to the respirator type.

Atmosphere-supplying respirator means a respirator that supplies the respirator user with breathing air from a source independent of the ambient atmosphere and includes supplied-air respirators and self-contained breathing apparatus units.

Fit test means the use of a protocol to qualitatively or quantitatively evaluate the fit of a respirator on an individual.

Powered air-purifying respirator means an air-purifying respirator that uses a blower to force the ambient air through air-purifying elements to the inlet covering.

Qualitative fit test means a pass/fail test to assess the adequacy of respirator fit that relies on the individual's response to the test agent.

Quantitative fit test means an assessment of the adequacy of respirator fit by numerically measuring the amount of leakage into the respirator.

Self-contained breathing apparatus means an atmosphere-supplying respirator for which the breathing air source is designed to be carried by the user.

Supplied-air respirator or airline respirator means an atmosphere- supplying respirator for which the source of breathing air is not designed to be carried by the user.

Respiratory Protection Program

This standard requires the employer to develop and implement a written respiratory protection program with required worksite-specific procedures and elements for required respirator use. The program must be administered by a suitably trained program administrator. In addition, certain program elements may be required for voluntary use to prevent potential hazards associated with the use of the respirator. The employer shall include in the written program the following information:

- Procedures for selecting respirators for use in the workplace
- Medical evaluations of employees required to use respirators
- Fit testing procedures
- Procedures for proper use of respirators
- Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators
- Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators
- Training required for respirator usage
- Procedures for evaluating the effectiveness of the program

Training and Information

This standard requires the employer to provide effective training to employees who are required to use respirators. The training must be comprehensive, must be understandable, and must recur annually, and more often, if necessary. Training must ensure that each employee can demonstrate knowledge and understanding of the topic, and include the following:

- Why respirator protection is necessary and how improper wearing or use can compromise the protection received
- Limitations and capabilities of the respirator and cartridge (filter)
- Inspection and maintenance procedures
- Cleaning, disinfecting, and storage procedures
- Proper wear of the respirator

Retraining shall be administered annually, or when a new process or procedure is implemented that the employee has not been previously trained.

Fall Protection Standard (29 CFR 1926.500-503)(Subpart M)

Scope and Application

This standard sets forth the requirements and criteria for fall protection in construction work areas covered by this standard. Exception: The provisions of this standard do not apply when employees are making inspection, investigation, or assessment of workplace conditions prior to the actual start of construction work or after all construction work has been completed.

Definitions

Anchorage means a secure point of attachment for lifelines, lanyards, or deceleration devices. Anchorage points must be rated to 5000 lb per person attached.

Body harness means straps that may be secured about the employee in a manner that will distribute the fall arrest forces over at least the thighs, pelvis, waist, chest, and shoulders with means for attaching it to other components of a personal fall arrest system.

Connector means a device that is used to couple parts of the personal fall arrest system and positioning device systems together.

Controlled access zone means an area in which certain work may take place without the use of guardrail systems, personal fall arrest systems, or safety net systems and access to the zone is controlled.

Deceleration device means any mechanism, such as a rope grab, rip-stitch lanyard, specially woven lanyard, tearing or deforming lanyards, automatic self-retracting lifelines/lanyards, and so on, that serves to dissipate a substantial amount of energy during a fall arrest, or otherwise limit the energy imposed on an employee during a fall arrest.

Deceleration distance means the additional vertical distance a falling employee travels, excluding lifeline elongation and free fall distance, before stopping, from the point at which the deceleration device begins to operate.

Free fall means the act of falling before a personal fall arrest system begins to apply force to arrest the fall.

Guardrail system means a barrier erected to prevent employees from falling to lower levels.

Lanyard means a flexible line of rope, wire rope, or strap that generally has a connector at each end for connecting the body harness to a deceleration device, lifeline, or anchorage.

Leading edge means the edge of a floor, roof, or formwork for a floor or other walking/working surface that changes location as additional floor, roof, decking, or formwork sections are placed, formed, or constructed. A leading edge is considered to be an "unprotected side and edge" during periods when it is not actively and continuously under construction.

Lifeline means a component consisting of a flexible line for connection to an anchorage at one end to hang vertically (vertical lifeline), or for connection to anchorages at both ends to stretch horizontally (horizontal lifeline), and which serves as a means for connecting other components of a personal fall arrest system to the anchorage.

Personal fall arrest system means a system used to arrest an employee in a fall from a working level. It consists of an anchorage, connectors, and body harness and may include a lanyard, deceleration device, lifeline, or suitable combinations of these.

Walking/working surface means any surface, whether horizontal or vertical, on which an employee walks or works, including, but not limited to, floors, roofs, ramps, bridges, runways, formwork, and concrete reinforcing steel, but not including ladders, vehicles, or trailers, on which employees must be located in order to perform their duties.

Duty to Have Fall Protection

The employer shall determine if the walking/working surfaces on which its employees are to work have the strength and structural integrity to support employees safely. Employees shall be allowed to work on those surfaces only when the surfaces have the requisite strength and structural integrity.

Each employee on a walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 6 ft or more above a lower level shall be protected from falling by the use of guardrail systems, safety net systems, or personal fall arrest system.

Training

The employer shall provide a training program for each employee who might be exposed to fall hazards. The program shall enable each employee to recognize the hazards of falling and shall train each employee in the procedures to be followed to minimize these hazards. The employer shall assure that each employee has been trained, as necessary, by a competent person qualified to teach the following information:

- Nature of fall hazards in the work area
- Correct procedures for erecting, maintaining, disassembling, and inspecting fall protection systems to be used

- Use and operation of guardrail systems, personal fall arrest systems, safety net systems, warning line systems, safety monitoring systems, controlled access zones, and other protection to be used
- The role of each employee in the safety monitoring system in which this system is used
- The limitations on the use of mechanical equipment during the performance of roofing work on low-sloped roofs
- Correct procedures for the handling and storage of equipment and materials and the erection of overhead protection
- The role of employers in fall protection plans
- The specific requirements of the standard

The employer shall verify compliance with the standard by preparing a written certification record. The written certification record shall contain the name or other identity of the employee trained, the date(s) of the training, and the signature of the person who conducted the training or the signature of the employer. The latest training certificate shall be maintained. When the employer has reason to believe that any affected employee who has already been trained does not have the understanding and skill required to work safely, the employer shall retrain each such employee or whenever new equipment, or systems are installed.

Respirable Crystalline Silica (29 CFR 1910.1053 and 29 CFR 1926.1153)

In recent years, the Occupational Safety and Health Administration (OSHA), as well as the Mine Safety and Health Administration (MSHA), has increased their focus on silica exposure and enforcement of safe work practices regarding employees. OSHA and the National Institute of Occupational Safety and Health (NIOSH) have designated silica as a health hazard for the general industry and construction industry. Some key tasks related to silica exposure may include:

- Manufacturing, finishing and installing natural and manufactured stones
- Abrasive blasting
- Sawing brick or concrete
- Sanding or drilling into concrete walls
- Grinding mortar
- Mining operations (not covered under OSHA Standard, however)

The silica permissible exposure limit (PEL) is 50 $\mu g/m^3$ and the action level (AL) is 25 $\mu g/m^3$, both of which are calculated as an 8-h time-weighted average (TWA).

Exposure Monitoring

The standard requires employers to assess the exposure of each employee who has exposure or who has potential exposure to respirable crystalline silica at or above the action level. This assessment includes conducting personal air monitoring to ensure that they are below the action level. This monitoring is performed initially to assess the 8-h TWA. If there are several employees who perform the same task, then a representative sample may be collected and analyzed to represent the group.

Monitoring result actions include:

- **Monitoring results below the action level**—If initial monitoring indicates exposures below the action level, then monitoring may be discontinued.
- **Monitoring results at or above the action level, but below the permissible exposure limit**, the employer shall repeat the monitoring within 6 months of the most recent testing.
- **If the most recent monitoring indicates employee exposures are at or above the permissible exposure limit, then the employer will retest within 3 months.**
- **Where the most recent (non-initial) exposure monitoring indicates exposure is below the action level**, the employer, the employer shall repeat monitoring within 6 months until two consecutive measurements, taken 7 or more days apart, are below the action level, the employee may discontinue monitoring for those employees whose exposure are represented by such monitoring.
- **Reassessment of exposures** is required when there is a change to the production, process, control equipment, personnel, or work practices that may reasonably be expected to result in new or addition exposures at or above the action level.

Regulated Areas

If employee exposure monitoring results indicate exposures greater than the PEL or have the potential to exceed the PEL, the employer shall establish regulated areas. These areas must be demarcated as regulated areas from the rest of the workplace in a manner that minimizes the number of employees exposed to respirable crystalline silica. Signage must be posted at all entrances to the regulated areas and access limited to authorized personnel who are required by their duties to be present in the designated areas.

Written Exposure Control Plan

The employer is required to develop, implement, and maintain a written exposure control plan that contains, at a minimum, the following elements:

- A description of the tasks in the workplace that involve exposure to respirable crystalline silica.
- A description of the engineering controls, work practices, and respiratory protection used to limit employee exposure to respirable crystalline silica for each task.
- A description of the housekeeping measures used to limit employee exposure to respirable crystalline silica.
- The employer shall review and evaluate the effectiveness of the written exposure control plan at least annually and update it, as necessary.
- The employer shall make the written exposure control plan readily available for examination and copying, upon request, to each employee covered by the regulation, or their designated representative and the Assistant Secretary and the Director.

Medical Surveillance

An employer is required to establish a medical surveillance program that includes each employee who is exposed to respirable crystalline silica at or above the action level for 30 or more days per year. All medical examinations are to be conducted by professional licensed health care providers (PLHCPs) at no cost to employees. The initial medical examination (baseline) is to be conducted within 30 days of assignment in an exposure environment. The examination is to include:

- Medical and work history (past, present and anticipated exposure to respirable crystalline silica)
- Physical examination with emphasis on the respiratory system
- Chest X-ray
- Pulmonary function test
- Testing for latent tuberculosis infection
- Any other tests deemed appropriate by the PLHCP

Key Information to Remember on Regulations

1. The Occupational Safety and Health Act (Public Law 91–596) was passed into law on December 29, 1970.

2. OSHA regulations do not apply to all employers in the public sector (municipal, county, state, or federal), self-employed individuals, family members operating a farm, or domestic household workers.
3. Horizontal standards are those standards that apply to all industries and employers.
4. Vertical standards are those standards that apply only to particular industries and employers.
5. Section 5(a)(1) of the OSH Act of 1970 is the General Duty Clause.
6. Once an employer receives a citation, he or she must post the citation in a conspicuous location for a period of 3 days or until the violation has been abated, whichever is longer.
7. If an employer decides to contest a citation or abatement period, or the proposed penalty, he or she has 15 working days from the time the citation or proposed penalty is received to notify the OSHA Area Director in writing.
8. If an employee who has received exposure to bloodborne pathogens refuses to take the hepatitis B vaccination, he or she must sign a refusal statement, which is maintained on file with the employer.
9. Employee medical records, under the bloodborne pathogen standard, must be maintained on file for the duration of employment plus 30 years.
10. A work-related recordable injury must be recorded on the OSHA 300 and 301 forms within seven working days of receiving notification of the injury or illness.
11. When an authorized government representative asks for records required in 29 CFR 1904, an employer must provide copies within 4 h.
12. A work-related fatality must be reported to OSHA within 8 h.
13. A worked-related injury resulting in in-patient hospitalization, amputation, or loss of an eye must be reported to OSHA within 24 h.

Comparison of Hazard Communication Requirements OSHA Hazard Communication Standard 29 CFR 1910.1200 (HCS) and Globally Harmonized System (GHS)

Introduction

The Globally Harmonized System (GHS) is not in itself a regulation or a model regulation. It is a framework from which competent authorities

may select the appropriate harmonized classification and communication elements. Competent authorities will decide how to apply the various elements of the GHS within their systems based on their needs and the target audience.

The GHS includes the following elements:

a. Harmonized criteria for classifying substances and mixtures according to their health, environmental, and physical hazards
b. Harmonized hazard communication elements, including requirements for labeling and material safety data sheets

The harmonized elements of the GHS may be seen as a collection of building blocks from which to form a regulatory approach. While the full range is available to everyone and should be used if a country or organization chooses to cover a certain effect when it adopts the GHS, the full range does not have to be adopted. This constitutes the GHS building block approach.

Competent authorities, such as OSHA, will determine how to implement the elements of the GHS within their systems. This document compares the GHS elements to the OSHA Hazard Communication Standard (HCS) elements. The competent authority allowances/decision points and the selection of building blocks are addressed in Section VI.

This Comparison of Hazard Communication Requirements document includes the following segments:

- General provisions comparison
- Health hazard comparison
- Physical hazard comparison
- Label comparison
- GHS and transport pictograms
- Label examples
- MSDS comparison
- GHS competent authority allowances and building block discussion

Purpose

Comparison

The purpose of the HCS and that of the GHS are consistent. The HCS is one of the major existing systems that was to be harmonized by the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
29 CFR 1910.1200 (a)(1) Purpose The purpose of this section is to ensure that the hazards of all chemicals produced or imported are evaluated and that information concerning their hazards is transmitted to employers and employees. This transmittal of information is to be accomplished by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, material safety data sheets, and employee training.	**1.1.1 Purpose** 1.1.1.1 The use of chemical products to enhance and improve life is a widespread practice worldwide. But alongside the benefits of these products, there is also the potential for adverse effects to people or the environment. As a result, a number of countries or organizations have developed laws or regulations over the years that require information to be prepared and transmitted to those using chemicals, through labels or Safety Data Sheets (SDSs). Given the large number of chemical products available, individual regulation of all of them is simply not possible for any entity. Provision of information gives those using chemicals the identities and hazards of these chemicals and allows the appropriate protective measures to be implemented in the local use settings.
(a)(2) This occupational safety and health standard is intended to address comprehensively the issue of evaluating the potential hazards of chemicals and communicating information concerning hazards and appropriate protective measures to employees and to preempt any legal requirements of a state, or political subdivision of a state, pertaining to this subject. Evaluating the potential hazards of chemicals, and communicating information concerning hazards and appropriate protective measures to employees, may include, for example, but is not limited to, provisions for developing and maintaining a written hazard communication program for the workplace, including Lists of hazardous chemicals present; labeling of containers of chemicals in the workplace, as well as of containers of chemicals being shipped to other workplaces; preparation and distribution of material safety data sheets to employees and downstream employers; and development and implementation of	1.1.1.2 While these existing laws or regulations are similar in many respects, their differences are significant enough to result in different labels or SDSs for the same product in different countries. Through variations in definitions of hazards, a chemical may be considered flammable in one country but not in another. Or it may be considered to cause cancer in one country but not in another. Decisions on when or how to communicate hazards on a label or SDS thus vary around the world, and companies wishing to be involved in international trade must have large staffs of experts who can follow the changes in these laws and regulations and prepare different labels and SDSs. In addition, given the complexity of developing and maintaining a comprehensive system for classifying and labeling chemicals, many countries have no system at all. 1.1.1.3 Given the reality of the extensive global trade in chemicals, and the need to develop national programs to ensure their safe use, transport, and disposal, it was recognized that an internationally harmonized approach to classification and labeling would provide the foundation for such programs. Once countries have consistent and appropriate information on the chemicals they import or produce in their own countries, the infrastructure to control chemical exposures and protect people and the environment can be established in a comprehensive manner.

(*Continued*)

Purpose	
Comparison	
The purpose of the HCS and that of the GHS are consistent. The HCS is one of the major existing systems that was to be harmonized by the GHS.	
OSHA HCS 29 CFR 1910.1200	**GHS**
employee training programs regarding hazards of chemicals and protective measures. Under Section 18 of the Act, no state or political subdivision of a state may adopt or enforce, through any court or agency, any requirement relating to the issue addressed by this Federal standard, except pursuant to a Federally approved state plan.	1.1.1.4 Thus, the reasons for setting the objective of harmonization were many. It is anticipated that, when implemented, the GHS will a. Enhance the protection of human health and the environment by providing an internationally comprehensible system for hazard communication b. Provide a recognized framework for those countries without an existing system c. Reduce the need for testing and evaluation of chemicals d. Facilitate international trade in chemicals whose hazards have been properly assessed and identified on an international basis 1.1.1.5 The work began with examination of existing systems and determination of the scope of the work. While many countries had some requirements, the following systems were deemed to be the "major" existing systems and were used as the primary basis for the elaboration of the GHS: a. Requirements of systems in the United States of America for the workplace, consumers, and pesticides b. Requirements of Canada for the workplace, consumers, and pesticides c. European Union directives for classification and labeling of substances and preparations d. The United Nations Recommendations on the Transport of Dangerous Goods 1.1.1.6 The requirements of other countries were also examined as the work developed, but the primary task was to find ways to adopt the best aspects of these existing systems and develop a harmonized approach. This work was done based on agreed principles of harmonization that were adopted early in the process: a. The level of protection offered to workers, consumers, the general public, and the environment should not be reduced as a result of harmonizing the classification and labeling systems. b. The hazard classification process refers principally to the hazards arising from the intrinsic properties of chemical elements and compounds and mixtures thereof, whether natural or synthetic. c. Harmonization means establishing a common and coherent basis for chemical hazard classification and communication, from which the appropriate elements relevant to means of transport, consumer, worker, and environment protection can be selected.

(*Continued*)

Purpose	
Comparison	
The purpose of the HCS and that of the GHS are consistent. The HCS is one of the major existing systems that was to be harmonized by the GHS.	
OSHA HCS 29 CFR 1910.1200	**GHS**
	d. The scope of harmonization includes both hazard classification criteria and hazard communication tools, for example, labeling and chemical safety data sheets, taking into account especially the four existing systems identified in the ILO report. e. Changes in all these systems will be required to achieve a single globally harmonized system; transitional measures should be included in the process of moving to the new system. f. The involvement of concerned international organizations of employers, workers, consumers, and other relevant organizations in the process of harmonization should be ensured. g. The comprehension of chemical hazard information, by the target audience, for example, workers, consumers, and the general public, should be addressed. h. Validated data already generated for the classification of chemicals under the existing systems should be accepted when reclassifying these chemicals under the harmonized system. i. A new harmonized classification system may require adaptation of existing methods for testing of chemicals. j. In relation to chemical hazard communication, the safety and health of workers, consumers, and the public in general, as well as the protection of the environment, should be ensured while protecting confidential business information, as prescribed by the competent authorities.

Scope

Comparison

The GHS scope clarification is consistent with the HCS exemptions and labeling exceptions. Consumer products and pharmaceuticals are specifically addressed in the GHS scope. The HCS includes laboratories, sealed containers, and distributors, while as a framework for systems, the GHS does not include these specific issues.

The GHS addresses testing in the scope section. The HCS addresses testing under hazard determination. The GHS and HCS do not require testing for health hazards. All the physical hazards in the HCS are not linked to specific test methods (as is the case in the GHS) and testing for physical hazards is not required.

OSHA HCS 29 CFR 1910.1200	GHS
29 CFR 1910.1200 (b) Scope and Application	**1.1.2 Scope**
(b)(1) This section requires chemical manufacturers or importers to assess the hazards of chemicals that they produce or import, and all employers to provide information to their employees about the hazardous chemicals to which they are exposed, by means of a hazard communication program, labels and other forms of warning, material safety data sheets, and information and training. In addition, this section requires distributors to transmit the required information to employers. (Employers who do not produce or import chemicals need only focus on those parts of this rule that deal with establishing a workplace program and communicating information to their workers. Appendix E of this section is a general guide for such employers to help them determine their compliance obligations under the rule.)	1.1.2.1 The GHS includes the following elements: a. Harmonized criteria for classifying substances and mixtures according to their health, environmental, and physical hazards b. Harmonized hazard communication elements, including requirements for labeling and safety data sheets
	1.1.2.2 This document describes the classification criteria and the hazard communication elements by type of hazard (e.g., acute toxicity, flammability). In addition, decision logics for each hazard have been developed. Some examples of classification of chemicals in the text, as well as in Annex 7, illustrate how to apply the criteria. There is also some discussion about issues that were raised during the development of the system where additional guidance was thought to be necessary to implement the system.
(b)(2) This section applies to any chemical that is known to be present in the workplace in such a manner that employees may be exposed under normal conditions of use or in a foreseeable emergency.	1.1.2.3 The scope of the GHS is based on the mandate from the 1992 United Nations Conference on Environment and Development (UNCED) for development of such a system as stated in paragraphs 26 and 27 of Agenda 21, Chapter 19, Program Area B, reproduced below:
(b)(3) This section applies to laboratories only as follows:	"26. Globally harmonized hazard classification and labeling systems are not yet available to promote the safe use of chemicals, inter alia, at the workplace or in the home. Classification of chemicals can be made for different purposes and is a particularly important tool in establishing labeling systems. There is a need to develop harmonized hazard classification and labeling systems, building on ongoing work;
(b)(3)(i) Employers shall ensure that labels on incoming containers of hazardous chemicals are not removed or defaced.	

(*Continued*)

Scope

Comparison

The GHS scope clarification is consistent with the HCS exemptions and labeling exceptions. Consumer products and pharmaceuticals are specifically addressed in the GHS scope. The HCS includes laboratories, sealed containers, and distributors, while as a framework for systems, the GHS does not include these specific issues.

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OSHA HCS 29 CFR 1910.1200	GHS
(b)(3)(ii) Employers shall maintain any material safety data sheets that are received with incoming shipments of hazardous chemicals and ensure that they are readily accessible during each work shift to laboratory employees when they are in their work areas. **(b)(3)(iii)** Employers shall ensure that laboratory employees are provided information and training in accordance with paragraph (h) of this section, except for the location and availability of the written hazard communication program under paragraph(h)(2)(iii) of this section. **(b)(3)(iv)** Laboratory employers that ship hazardous chemicals are reconsidered to be either a chemical manufacturer or a distributor under this rule, and thus must ensure that any containers of hazardous chemicals leaving the laboratory are labeled in accordance with paragraph (f)(1) of this section and that a material safety data sheet is provided to distributors and other employers in accordance with paragraphs (g)(6) and (g)(7) of this section. **(b)(4)** In work operations where employees only handle chemicals in sealed containers that are not opened under normal conditions of use (such as are found in marine cargo handling, warehousing, or retail sales), this section applies to these operations only as follows:	27. *A globally harmonized hazard classification and compatible labeling system, including material safety data sheets and easily understandable symbols, should be available, if feasible, by the year 2000. "* This mandate was later analyzed and refined in the harmonization process to identify the parameters of the GHS. As a result, the following clarification was adopted by the Interorganization Program for the Sound Management of Chemicals (IOMC) Coordinating Group to ensure that participants were aware of the scope of the effort: *"The work on harmonization of hazard classification and labeling focuses on a harmonized system for all chemicals, and mixtures of chemicals. The application of the components of the system may vary by type of product or stage of the life cycle. Once a chemical is classified, the likelihood of adverse effects may be considered in deciding what informational or other steps should be taken for a given product or use setting. Pharmaceuticals, food additives, cosmetics, and pesticide residues in food will not be covered by the GHS in terms of labeling at the point of intentional intake. However, these types of chemicals would be covered where workers may be exposed, and, in transport if potential exposure warrants. The Coordinating Group for the Harmonization of Chemical Classification Systems (CG/HCCS) recognizes that further discussion will be required to address specific application issues for some product use categories which may require the use of specialized expertise."* 1.1.2.5 In developing this clarification, the CG/HCCS carefully considered many different issues with regard to the possible application of the GHS. There were concerns raised about whether certain sectors or products should be exempted, for example, or about whether or not the system would be applied at all stages of the life cycle of a chemical. Three parameters were agreed in this discussion and are critical to application of the system in a country or region. These are described below:

(*Continued*)

Scope

Comparison

The GHS scope clarification is consistent with the HCS exemptions and labeling exceptions. Consumer products and pharmaceuticals are specifically addressed in the GHS scope. The HCS includes laboratories, sealed containers, and distributors, while as a framework for systems, the GHS does not include these specific issues.

The GHS addresses testing in the scope section. The HCS addresses testing under hazard determination. The GHS and HCS do not require testing for health hazards. All the physical hazards in the HCS are not linked to specific test methods (as is the case in the GHS) and testing for physical hazards is not required.

OSHA HCS 29 CFR 1910.1200	GHS
(b)(4)(i) Employers shall ensure that labels on incoming containers of hazardous chemicals are not removed or defaced. **(b)(4)(ii)** Employers shall maintain copies of any material safety data sheets that are received with incoming shipments of the sealed containers of hazardous chemicals, shall obtain a material safety data sheet as soon as possible for sealed containers of hazardous chemicals received without a material safety data sheet if an employee requests the material safety data sheet, and shall ensure that the material safety data sheets are readily accessible during each work shift to employees when they are in their work area(s). (b)(4)(iii) Employers shall ensure that employees are provided with information and training in accordance with paragraph (h) of this section (except for the location and availability of the written hazard communication program under paragraph (h)(2)(iii) of this section), to the extent necessary to protect them in the event of a spill or leak of a hazardous chemical from a sealed container. (b)(5) This section does not require labeling of the following chemicals: (b)(5)(i) Any pesticide as such term is defined in the Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. 136 et seq.), when subject to the labeling requirements of that Act and labeling regulations issued under that Act by the Environmental Protection Agency.	a. Parameter 1: The GHS covers all hazardous chemicals. The mode of application of the hazard communication components of the GHS (e.g., labels, safety data sheets) may vary by product category or stage in the life cycle. Target audiences for the GHS include consumers, workers, transport workers, and emergency responders i. Existing hazard classification and labeling systems address potential exposures to all potentially hazardous chemicals in all types of use situations, including production, storage, transport, workplace use, consumer use, and presence in the environment. They are intended to protect people, facilities, and the environment. The most widely applied requirements in terms of chemicals covered are generally found in the parts of existing systems that apply to the workplace or transport. It should be noted that the term chemical is used broadly in the UNCED agreements and subsequent documents to include substances, products, mixtures, preparations, or any other terms that may be used in existing systems to denote coverage. ii. Since all chemicals and chemical products in commerce are made in a workplace (including consumer products), handled during shipment and transport by workers, and often used by workers, there are no complete exemptions from the scope of the GHS for any particular type of chemical or product. In some countries, for example, pharmaceuticals are currently covered by workplace and transport requirements in the manufacturing, storage, and transport stages of the life cycle. Workplace requirements may also be applied to employees involved in the administration of some drugs, or cleanup of spills and other types of potential exposures in health care settings. SDSs and training must be available for these employees under some systems. It is anticipated that the GHS would be applied to pharmaceuticals in a similar fashion. iii. At other stages of the life cycle for these same products, the GHS may not be applied at all. For example, at the point of intentional human intake or ingestion, or intentional application to animals, products such as human or veterinary pharmaceuticals are generally not subject to

(*Continued*)

Scope

Comparison

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The GHS addresses testing in the scope section. The HCS addresses testing under hazard determination. The GHS and HCS do not require testing for health hazards. All the physical hazards in the HCS are not linked to specific test methods (as is the case in the GHS) and testing for physical hazards is not required.

OSHA HCS 29 CFR 1910.1200	GHS
(b)(5)(ii) Any chemical substance or mixture as such terms redefined in the Toxic Substances Control Act (15 U.S.C. 2601 et seq.), when subject to the labeling requirements of that Act and labeling regulations issued under that Act by the Environmental Protection Agency. (b)(5)(iii) Any food, food additive, color additive, drug, cosmetic, or medical or veterinary device or product, including materials intended for use as ingredients in such products (e.g., flavors and fragrances), as such terms are defined in the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 301 et seq.) or the Virus-Serum-Toxin Act of 1913 (21 U.S.C. 151 et seq.), and regulations issued under those Acts, when they are subject to the labeling requirements under those Acts by either the Food and Drug Administration or the Department of Agriculture. **(b)(5)(iv)** Any distilled spirits (beverage alcohols), wine, or malt beverage intended for nonindustrial use, as such terms are defined in the Federal Alcohol Administration Act (27 U.S.C. 201 et seq.) and regulations issued under that Act, when subject to the labeling requirements of that Act and labeling regulations issued under that Act by the Bureau of Alcohol, Tobacco, and Firearms. **(b)(5)(v)** Any consumer product or hazardous substance as those terms are defined in the Consumer Product Safety Act (15 U.S.C. 2051 et seq.) and Federal Hazardous Substances Act (15 U.S.C. 1261 et seq.), respectively, when subject to a consumer product safety standard or labeling requirement of those Acts, or regulations issued under those Acts by the Consumer Product Safety Commission.	hazard labeling under existing systems. Such requirements would not normally be applied to these products as a result of the GHS. (It should be noted that the risks to subjects associated with the medical use of human or veterinary pharmaceuticals are generally addressed in package inserts and are not part of this harmonization process.) Similarly, products such as foods that may have trace amounts of food additives or pesticides in them are not currently labeled to indicate the presence or hazard of those materials. It is anticipated that application of the GHS would not require them to be labeled as such. **b. Parameter 2: The mandate for development of a GHS does not include establishment of uniform test methods or promotion of further testing to address adverse health outcomes,** i. Tests that determine hazardous properties, which are conducted according to internationally recognized scientific principles, can be used for purposes of a hazard determination for health and environmental hazards. The GHS criteria for determining health and environmental hazards are test method neutral, allowing different approaches as long as they are scientifically sound and validated according to international procedures and criteria already referred to in existing systems for the hazard class of concern and produce mutually acceptable data. While the OECD is the lead organization for development of harmonized health hazard criteria, the GHS is not tied to the OECD Test Guidelines Program. For example, drugs are tested according to agreed criteria developed under the auspices of the World Health Organization (WHO). Data generated in accordance with these tests would be acceptable under the GHS. Criteria for physical hazards under the UNSCETDG are linked to specific test methods for hazard classes such as flammability and explosivity. ii. The GHS is based on currently available data. Since the harmonized classification criteria are developed on the basis of existing data, compliance with these criteria will not require retesting of chemicals for which accepted test data already exist. c. Parameter 3: In addition to animal data and valid in vitro testing, human experience, epidemiological data, and clinical testing provide important information that should be considered in application of the GHS.

(*Continued*)

Scope

Comparison

The GHS scope clarification is consistent with the HCS exemptions and labeling exceptions. Consumer products and pharmaceuticals are specifically addressed in the GHS scope. The HCS includes laboratories, sealed containers, and distributors, while as a framework for systems, the GHS does not include these specific issues.

The GHS addresses testing in the scope section. The HCS addresses testing under hazard determination. The GHS and HCS do not require testing for health hazards. All the physical hazards in the HCS are not linked to specific test methods (as is the case in the GHS) and testing for physical hazards is not required.

OSHA HCS 29 CFR 1910.1200	GHS
(b)(5)(vi) Agricultural or vegetable seed treated with pesticides and labeled in accordance with the Federal Seed Act (7 U.S.C. 1551 et seq.) and the labeling regulations issued under that Act by the Department of Agriculture. **(b)(6)** This section does not apply to the following: **(b)(6)(i)** Any hazardous waste as such term is defined by the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, as amended (42 U.S.C. 6901 et seq.), when subject to regulations issued under that Act by the Environmental Protection Agency. (b)(6)(ii) Any hazardous substance as such term is defined by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 U.S.C. 9601 et seq.) when the hazardous substance is the focus of remedial or removal action being conducted under CERCLA in accordance with the Environmental Protection Agency regulations. (b)(6)(iii) Tobacco or tobacco products.	Most of the current systems acknowledge and make use of ethically obtained human data or available human experience. Application of the GHS should not prevent the use of such data, and the GHS explicitly acknowledges the existence and use of all appropriate and relevant information concerning hazards or the likelihood of harmful effects (i.e., risk). 1.1.2.6 Other scope limitations 1.1.2.6.1 The GHS is not intended to harmonize risk assessment procedures or risk management decisions (such as establishment of a permissible exposure limit for employee exposure), which generally require some risk assessment in addition to hazard classification. In addition, chemical inventory requirements in various countries are not related to the GHS

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Scope

Comparison

The GHS scope clarification is consistent with the HCS exemptions and labeling exceptions. Consumer products and pharmaceuticals are specifically addressed in the GHS scope. The HCS includes laboratories, sealed containers, and distributors, while as a framework for systems, the GHS does not include these specific issues.

The GHS addresses testing in the scope section. The HCS addresses testing under hazard determination. The GHS and HCS do not require testing for health hazards. All the physical hazards in the HCS are not linked to specific test methods (as is the case in the GHS) and testing for physical hazards is not required.

OSHA HCS 29 CFR 1910.1200	GHS
(b)(6)(iv) Wood or wood products, including lumber that will not be processed, where the chemical manufacturer or importer can establish that the only hazard they pose to employees is the potential for flammability or combustibility (wood or wood products that have been treated with a hazardous chemical covered by this standard and wood that may be subsequently sawed or cut, generating dust, are not exempted). (b)(6)(v) Articles (as that term is defined in paragraph (c) of this section). (b)(6)(vi) Food or alcoholic beverages that are sold, used, or prepared in a retail establishment (such as a grocery store, restaurant, or drinking place), and foods intended for personal consumption by employees while in the workplace. **(b)(6)(vii)** Any drug, as that term is defined in the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 301 et seq.), when it is in solid, final form for direct administration to the patient (e.g., tablets or pills); drugs that are packaged by the chemical manufacturer for sale to consumers in a retail establishment (e.g., over-the-counter drugs); and drugs intended for personal consumption by employees while in the workplace (e.g., first-aid supplies).	

(*Continued*)

Scope

Comparison

The GHS scope clarification is consistent with the HCS exemptions and labeling exceptions. Consumer products and pharmaceuticals are specifically addressed in the GHS scope. The HCS includes laboratories, sealed containers, and distributors, while as a framework for systems, the GHS does not include these specific issues.

The GHS addresses testing in the scope section. The HCS addresses testing under hazard determination. The GHS and HCS do not require testing for health hazards. All the physical hazards in the HCS are not linked to specific test methods (as is the case in the GHS) and testing for physical hazards is not required.

OSHA HCS 29 CFR 1910.1200	GHS
(b)(6)(viii) Cosmetics that are packaged for sale to consumers in a retail establishment and cosmetics intended for personal consumption by employees while in the workplace.	
(b)(6)(ix) Any consumer product or hazardous substance, as those terms are defined in the Consumer Product Safety Act (15 U.S.C. 2051 et seq.) and Federal Hazardous Substances Act (15 U.S.C. 1261 et seq.), respectively, where the employer can show that it is used in the workplace for the purpose intended by the chemical manufacturer or importer of the product, and the use results in a duration and frequency of exposure that is not greater than the range of exposures that could reasonably be experienced by consumers when used for the purpose intended.	
(b)(6)(x) Nuisance particulates where the chemical manufacturer or importer can establish that they do not pose any physical or health hazard covered under this section.	
(b)(6)(xi) Ionizing and nonionizing radiation.	
(b)(6)(xii) Biological hazards.Ul	

Application

Comparison

Implementing the GHS will require the HCS to make decisions concerning the application of the building blocks for physical and health hazard classes and hazard categories. See the individual health and physical endpoints for details. For other competent authority decisions, see GHS competent authority allowances and building block discussion section.

OSHA HCS 29 CFR 1910.1200	GHS
Comment: The HCS is a performance-oriented regulation. The GHS is specification oriented. Implementation of the GHS will require changes to the performance-oriented nature of the HCS. These changes will include required label elements and a required MSDS format, as well as criteria changes. Although the GHS has the building block approach, changes to the HCS are expected. The HCS may not implement all hazard classes, for example, hazardous for the environment. Even within some hazard classes, the HCS may not regulate all hazard categories, for example, acute toxicity. Many hazard classes will require some type of change to the HCS.	1.1.3 Application of the GHS 1.1.3.1 Harmonization of the application of the GHS 1.1.3.1.1 The goal of the GHS is to identify the intrinsic hazards found in chemical substances and mixtures and to convey hazard information about these hazards. The criteria for hazard classification are harmonized. Hazard statements, symbols, and signal words have been standardized and harmonized and are now part of a foreman-integrated hazard communication system. The GHS will allow the hazard communication elements of the existing systems to converge. Competent authorities will decide how to apply the various elements of the GHS on the basis of the needs of the competent authority and the target audience. (See also Hazard Communication: Labeling (Chapter 1.4, paragraph 1.4.10.5.4.2) and Consumer Product Labeling Based on the Likelihood of Injury, Annex 4.) 1.1.3.1.2 For transport, it is expected that application of the GHS will be similar to application of current transport requirements. Containers of dangerous goods will be marked with pictograms that address acute toxicity, physical hazards, and environmental hazards. As is true for workers in other sectors, workers in the transport sector will be trained. The elements of the GHS that address such elements as signal words and hazard statements are not expected to be adopted in the transport sector. 1.1.3.1.3 In the workplace, it is expected that all of the GHS elements will be adopted, including labels that have the harmonized core information under the GHS and safety data sheets. It is also anticipated that this will be supplemented by employee training to help ensure effective communication. 1.1.3.1.4. For the consumer sector, it is expected that labels will be the primary focus of GHS application. These labels will include the core elements of the GHS, subject to some sector-specific considerations in certain systems. (See also Hazard Communication: Labeling (Chapter 1.4, paragraph 1.4.10.5.4.2) and Consumer Product Labeling Based on the Likelihood of Injury, Annex 4.)

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Application	
Comparison Implementing the GHS will require the HCS to make decisions concerning the application of the building blocks for physical and health hazard classes and hazard categories. See the individual health and physical endpoints for details. For other competent authority decisions, see GHS competent authority allowances and building block discussion section.	
OSHA HCS 29 CFR 1910.1200	**GHS**
	1.1.3.1.5 Building block approach. 1.1.3.1.5.1 Consistent with the building block approach, countries are free to determine which of the building blocks will be applied in different parts of their systems. However, where a system covers something that is in the GHS, and implements the GHS, that coverage should be consistent. For example, if a system covers the carcinogenicity of a chemical, it should follow the harmonized classification scheme and the harmonized label elements. 1.1.3.1.5.2 In examining the requirements of existing systems, it was noted that coverage of hazards may vary by the perceived needs of the target audience for information. In particular, the transport sector focuses on acute health effects and physical hazards but has not to date covered chronic effects owing to the types of exposures expected to be encountered in that setting. But there may be other differences as well, with countries choosing not to cover all of the effects addressed by the GHS in each use setting. 1.1.3.1.5.3 The harmonized elements of the GHS may thus be seen as a collection of building blocks from which to form a regulatory approach. While the full range is available to everyone, and should be used if a country or organization chooses to cover a certain effect when it adopts the GHS, the full range does not have to be adopted. While physical hazards are important in the workplace and transport sectors, consumers may not need to know some of the specific physical hazards in the type of use they have for a product. As long as the hazards covered by a sector or system are covered consistently with the GHS criteria and requirements, it will be considered appropriate implementation of the GHS. Notwithstanding the fact that an exporter needs to comply with importing countries' GHS implementation, it is hoped that the application of the GHS worldwide will eventually lead to a fully harmonized situation.

Definitions

Comparison

The HCS will need to add definitions and some existing HCS definitions will need to be changed. The above definitions illustrate some of the key changes to be considered. Substance, chemical, liquid, and gas are some differences. In the HCS, physical hazards have definitions. The GHS has criteria for physical hazards.

OSHA HCS 29 CFR 1910.1200	GHS
"Chemical" means any element, chemical compound, or mixture of elements or compounds.	Substance means chemical elements and their compounds in the natural state or obtained by any production process, including any additive necessary to preserve the stability of the product and any impurities deriving from the process used, but excluding any solvent that may be separated without affecting the stability of the substance or changing its composition.
"Chemical name" means the scientific designation of a chemical in accordance with the nomenclature system developed by the International Union of Pure and Applied Chemistry (IUPAC) or the Chemical Abstracts Service (CAS) rules of nomenclature, or a name that will clearly identify the chemical for the purpose of conducting a hazard evaluation. "Specific chemical identity" means the chemical name, Chemical Abstracts Service (CAS) Registry Number, or any other information that reveals the precise chemical designation of the substance.	Chemical identity means a name that will uniquely identify a chemical. This can be a name that is in accordance with the nomenclature systems of the International Union of Pure and Applied Chemistry (IUPAC) or the Chemical Abstracts Service (CAS), or a technical name.
"Combustible liquid" means any liquid having a flagship at or above 100°F (37.8°C) but below 200°F (93.3°C), except any mixture having components with flash points of 200°F (93.3°C) or higher, the total volume of which make up 99% or more of the total volume of the mixture.	**See flammable liquid hazard categories.**
"Common name" means any designation or identification such as code name, code number, trade name, brand name, or generic name used to identify a chemical other than by its chemical name.	No GHS definition.

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Definitions

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OSHA HCS 29 CFR 1910.1200	GHS
"Compressed gas" means i. A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C) ii. A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C) iii. A liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72	Compressed gas: A gas that when packaged under pressure is entirely gaseous at –50°C, including all gases with a critical temperature <–50°C.
No HCS definition.	Corrosive to metal means a substance or a mixture that, by chemical action, will materially damage, or even destroy, metals.
"Explosive" means a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.	Explosive article means an article containing one or more explosive substances. Explosive substance means a solid or liquid substance (or mixture of substances) that is in itself capable, by chemical reaction, of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. Pyrotechnic substances are included even when they do not evolve gases.
"Flammable" means a chemical that falls into one of the following categories: i. "Aerosol, flammable" means an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening.	Flammable gas: A gas having a flammable range with air at 20°C and a standard pressure of 101.3 kPa. Flammable liquid: A liquid having a flash point of not more than 93°C. Flammable solid: A solid that is readily combustible or may cause or contribute to fire through friction.

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Definitions

Comparison

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OSHA HCS 29 CFR 1910.1200	GHS
ii. "Gas, flammable" means a. A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% by volume or less b. A gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of the lower limit	**Aerosols** means any nonrefillable receptacles made of metal, glass, or plastics containing a gas compressed, liquefied, or dissolved under pressure, with or without a liquid, paste or powder, and fitted with a release device allowing the contents to be ejected as solid or liquid particles in suspension in a gas, as a foam, paste, or powder or in a liquid state or in a gaseous state. Aerosol includes aerosol dispensers.
iii. "Liquid, flammable" means any liquid having a flash point below 100°F (37.8°C), except any mixture having components with flash points of 100°F (37.8°C) or higher, the total of which make up 99% or more of the total volume of the mixture.	**Readily combustible solid:** Readily combustible solids are powdered, granular, or pasty substances that are dangerous if they can be easily ignited by brief contact with an ignition source, such as a burning match, and if the flame spreads rapidly.
iv. "Solid, flammable" means a solid, other than a blasting agent or explosive as defined in 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.	
"Flash point" means the minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite when tested as follows:	**Flash point** means the lowest temperature (corrected to a standard pressure of 101.3 kPa) at which the application of an ignition source causes the vapors of a liquid to ignite under specified test conditions.

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Definitions

Comparison

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OSHA HCS 29 CFR 1910.1200	GHS
i. Tagliabue Closed Tester (see American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24-1979(ASTM D 56-79)) for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100°F (37.8°C) that do not contain suspended solids and do not have a tendency to form a surface film under test ii. Pensky-Martens Closed Tester (see American National Standard Method of Test for Flash Point by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D 93-79)) for liquids with a viscosity equal to or greater than 45 SUS at 100°F (37.8°C), or that contain suspended solids, or that have a tendency to form a surface film under test iii. Setaflash Closed Tester (see American National Standard Method of Test for Flash Point by Setaflash Closed Tester (ASTM D3278-78)).	
No HCS definition.	Gas means a substance that (i) at 50°C has a vapor pressure greater than 300 kPa or (ii) is completely gaseous at 20°C at a standard pressure of 101.3 kPa. Dissolved gas means a gas that, when packaged under pressure, is dissolved in a liquid phase solvent. Liquefied gas means a gas that, when packaged under pressure, is partially liquid at temperatures above –50°C. A distinction is made between the following: i. High-pressure liquefied gas: a gas with a critical temperature between –50°C and +65°C ii. Low-pressure liquefied gas: a gas with a critical temperature above +65°C Refrigerated liquefied gas: A gas that when packaged is made partially liquid because of its low temperature.

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Definitions

Comparison

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OSHA HCS 29 CFR 1910.1200	GHS
"Health hazard" means a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term *health hazard* includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes. Appendix A provides further definitions and explanations of the scope of health hazards covered by this section, and Appendix B describes the criteria to be used to determine whether or not a chemical is to be considered hazardous for purposes of this standard. (See appendix for criteria.)	**Hazard category** means the division of criteria within each hazard class; for example, oral acute toxicity includes five hazard categories and flammable liquids includes four hazard categories. These categories compare hazard severity within a hazard class and should not be taken as a comparison of hazard categories more generally. **Hazard class** means the nature of the physical, health, or environmental hazard, for example, flammable solid carcinogen and oral acute toxicity.
"Hazard warning" means any words, pictures, symbols, or combination thereof appearing on a label or other appropriate forms of warning that convey the specific physical and health hazard(s), including target organ effects, of the chemical(s) in the container(s). (See the definitions for "physical hazard" and "health hazard" to determine the hazards that must be covered.)	**Hazard statement** means a statement assigned to a hazard class and category that describes the nature of the hazards of a hazardous product, including, where appropriate, the degree of hazard. **Signal word:** A signal word means a word used to indicate the relative level of severity of hazard and alert the reader to a potential hazard on the label. The GHS uses "Danger" and "Warning." **Pictogram:** A pictogram means a composition that may include a symbol plus other graphic elements, such as a border, background pattern, or color, that is intended to convey specific information. **Precautionary statement:** A precautionary statement means a phrase (and/or a pictogram) that describes recommended measures that should be taken to minimize or prevent adverse effects resulting from exposure to a hazardous product or improper storage or handling of a hazardous product.

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Definitions	
Comparison The HCS will need to add definitions and some existing HCS definitions will need to be changed. The above definitions illustrate some of the key changes to be considered. Substance, chemical, liquid, and gas are some differences. In the HCS, physical hazards have definitions. The GHS has criteria for physical hazards.	
OSHA HCS 29 CFR 1910.1200	**GHS**
	Supplemental label element: A supplemental label element means any additional nonharmonized type of information supplied on the container of a hazardous product that is not required or specified under the GHS. In some cases, this information may be required by other competent authorities or it may be additional information provided at the discretion of the manufacturer/distributor. Symbol: A symbol means a graphical element intended to succinctly convey information.
"Label" means any written, printed, or graphic material displayed on or affixed to containers of hazardous chemicals.	Label means an appropriate group of written, printed, or graphic information elements concerning a hazardous product, selected as relevant to the target sector(s), that is affixed to, printed on, or attached to the immediate container of a hazardous product or to the outside packaging of a hazardous product. **Label element** means one type of information that has been harmonized for use in a label, for example, pictogram or signal word.
No HCS definition	Liquid means a substance or mixture that at 50°C has a vapor pressure of not more than 300 kPa (3 bar), that is not completely gaseous at 20°C and at a standard pressure of 101.3 kPa, and that has a melting point or initial melting point of 20°C or less at a standard pressure of 101.3 kPa. A viscous substance or mixture for which a specific melting point cannot be determined shall be subjected to the ASTM D 4359–90 test or to the test for determining fluidity (penetrometer test) prescribed in Section 2.3.4 of Annex A of the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR).

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Definitions

Comparison

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OSHA HCS 29 CFR 1910.1200	GHS
"Mixture" means any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.	**Mixture** means a mixture or a solution composed of two or more substances in which they do not react. **Alloy** means a metallic material, homogeneous on a macroscopic scale, consisting of two or more elements so combined that they cannot be readily separated by mechanical means. Alloys are considered to be mixtures for the purpose of classification under the GHS.
"Oxidizer" means a chemical other than a blasting agent or explosive as defined in 1910.109(a) that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.	**Oxidizing gas** means any gas that may, generally by providing oxygen, cause or contribute to the combustion of other material more than air does. **Oxidizing liquid** means a liquid that, while in itself not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material. **Oxidizing solid** means a solid that, while in itself not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material.
"Organic peroxide" means an organic compound that contains the bivalent -O-O- structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms have been replaced by an organic radical.	**Organic peroxide** means a liquid or solid organic substance which contains the bivalent -O-O- structure and may be considered a derivative of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals. The term also includes organic peroxide formulation (mixtures).
"Identity" means any chemical or common name that is indicated on the material safety data sheet (MSDS) for the chemical. The identity used shall permit cross-references to be made among the required list of hazardous chemicals, the label, and the MSDS.	**Product identifier:** A product identifier means the name or number used for a hazardous product on a label or in the SDS. It provides a unique means by which the product user can identify the substance or mixture within the particular use setting, for example, transport, consumer, or workplace.

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Definitions

Comparison

The HCS will need to add definitions and some existing HCS definitions will need to be changed. The above definitions illustrate some of the key changes to be considered. Substance, chemical, liquid, and gas are some differences. In the HCS, physical hazards have definitions. The GHS has criteria for physical hazards.

OSHA HCS 29 CFR 1910.1200	GHS
"Pyrophoric" means a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.	**Pyrophoric liquid:** A pyrophoric liquid is a liquid that, even in small quantities, is liable to ignite within 5 min after coming into contact with air. **Pyrophoric solid:** *A* pyrophoric solid is a solid that, even in small quantities, is liable to ignite within 5 min after coming into contact with air. **Pyrotechnic substance:** *A* substance or mixture of substances designed to produce an effect by heat, light, sound, gas, or smoke or a combination of these as a result of nondetonative self-sustaining exothermic chemical reactions
No HCS definition.	Technical name: A name that is generally used in commerce, regulations, and codes to identify a substance or mixture, other than the IUPAC or CAS name, and that is recognized by the scientific community. Examples of technical names include those used for complex mixtures (e.g., petroleum fractions or natural products), pesticides (e.g., ISO or ANSI systems), dyestuffs (Color Index system), and minerals.
"Trade secret" means any confidential formula, pattern, process, device, information, or compilation of information that is used in an employer's business that gives the employer an opportunity to obtain an advantage over competitors who do not know or use it. Appendix D sets out the criteria to be used in evaluating trade secrets.	CBI means "confidential business information."

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Definitions

Comparison

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OSHA HCS 29 CFR 1910.1200	GHS
"Unstable (reactive)" means a chemical that in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shock, pressure, or temperature. "Pyrophoric" means a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.	Self-heating substance: A self-heating substance is a solid or liquid substance, other than a pyrophoric substance, which, by reaction with air and without energy supply, is liable to self-heat; this substance differs from a pyrophoric substance in that it will ignite only when in large amounts (kilograms) and after long periods of time (hours or days).
"Unstable (reactive)" means a chemical that in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shock, pressure, or temperature.	Self-reactive substance: Self-reactive substances are thermally unstable liquid or solid substances liable to undergo a strongly exothermic decomposition even without participation of oxygen (air). This definition excludes substances or mixtures classified under the GHS as explosive, organic peroxides, or oxidizing.
"Water reactive" means a chemical that reacts with water to release a gas that is either flammable or presents a health hazard.	Substances that, in contact with water, emit flammable gases are solid or liquid substances that, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

Hazard Determination/Classification

Comparison

A significant difference between the HCS and GHS is the evaluation of mixtures. The GHS criteria for mixtures vary by hazard class. See individual endpoints for details. The HCS allows test data on mixtures to be used for all hazard classes. The GHS allows test data on carcinogens, mutagens, and reproductive toxins on a case-by-case basis. The GHS expectation of physical test data for mixtures is another difference.

The HCS "floor" of hazardous chemicals is a difference and one that is likely helpful to small businesses. Guidance on how IARC, NTP, and OSHA carcinogens fit with the GHS cancer classification scheme could also be useful guidance.

OSHA HCS 29 CFR 1910.1200	GHS
1910.1200(d) Hazard Determination	1.3.2 General considerations on the GHS
(d)(1)	1.3.2.1 Scope of the system
Chemical manufacturers and importers shall evaluate chemicals produced in their workplaces or imported by them to determine if they are hazardous. Employers are not required to evaluate chemicals unless they choose not to rely on the evaluation performed by the chemical manufacturer or importer for the chemical to satisfy this requirement.	1.3.2.1.1 The GHS applies to pure chemical substances, their dilute solutions, and mixtures of chemical substances. "Articles" as defined in the Hazard Communication Standard (29 CFR 1910.1200) of the US Occupational Safety and Health Administration, or by similar definition, are outside the scope of the system.
(d)(2)	1.3.2.1.2 One objective of the GHS is for it to be simple and transparent with a clear distinction between classes and categories in order to allow for "self-classification" as far as possible. For many hazard classes, the criteria are semiquantitative or qualitative and expert judgment is required to interpret the data for classification purposes. Furthermore, for some hazard classes (e.g., eye irritation, explosives, or self-reactive substances), a decision tree approach is provided to enhance ease of use.
Chemical manufacturers, importers, or employers evaluating chemicals shall identify and consider the available scientific evidence concerning such hazards. For health hazards, evidence that is statistically significant and that is based on at least one positive study conducted in accordance with established scientific principles is considered to be sufficient to establish a hazardous effect if the results of the study meet the definitions of health hazards in this section. Appendix A shall be consulted for the scope of health hazards covered, and Appendix B shall be consulted for the criteria to be followed with respect to the completeness of the evaluation and the data to be reported.	1.3.2.2 Concept of "classification" 1.3.2.2.1 The GHS uses the term *hazard classification* to indicate that only the intrinsic hazardous properties of substances or mixtures are considered. 1.3.2.2.2 Hazard classification incorporates only three steps, that is: a. Identification of relevant data regarding the hazards of a substance or mixture b. Subsequent review of those data to ascertain the hazards associated with the substance or mixture
(d)(3)	
The chemical manufacturer, importer, or employer evaluating chemicals shall treat the following sources as establishing that the chemicals listed in them are hazardous:	

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Hazard Determination/Classification

Comparison

A significant difference between the HCS and GHS is the evaluation of mixtures. The GHS criteria for mixtures vary by hazard class. See individual endpoints for details. The HCS allows test data on mixtures to be used for all hazard classes. The GHS allows test data on carcinogens, mutagens, and reproductive toxins on a case-by-case basis. The GHS expectation of physical test data for mixtures is another difference.

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OSHA HCS 29 CFR 1910.1200	GHS
(d)(3)(i) 29 CFR part 1910, subpart Z, Toxic and Hazardous Substances, Occupational Safety and Health Administration (OSHA).	c. A decision on whether the substance or mixture will be classified as a hazardous substance or mixture and the degree of hazard, where appropriate, by comparison of the data with agreed hazard classification criteria
(d)(3)(ii) "Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment," American Conference of Governmental Industrial Hygienists (ACGIH) (latest edition). The chemical manufacturer, importer, or employer is still responsible for evaluating the hazards associated with the chemicals in these source lists in accordance with the requirements of this standard.	1.3.2.2.3 As noted in IOMC Description and Further Clarification of the Anticipated Application of the GHS text in the Purpose, Scope and Application (Chapter 1.1, paragraph 1.3.2.3 Classification criteria (mixtures) The classification criteria for substances and mixtures are presented in Parts 2 and 3 of this document, each of which is for a specific hazard class or a group of closely related hazard classes. The recommended process of classification of mixtures is based on the following sequence:
(d)(4) Chemical manufacturers, importers, and employers evaluating chemicals shall treat the following sources as establishing that a chemical is a carcinogen or potential carcinogen for hazard communication purposes:	a. Where test data are available for the complete mixture, the classification of the mixture will always be based on that data. b. Where test data are not available for the mixture itself, then bridging principles included and explained in each specific chapter should be considered to see whether they permit classification of the mixture. In addition, for the health and environmental classes, c. If (i) test data are not available for the mixture itself and (ii) the available information is not sufficient to allow application of the abovementioned bridging principles, then the agreed method(s) described in each chapter for estimating the hazards based on the information known will be applied to classify the mixture.
(d)(4)(i) National Toxicology Program (NTP), "Annual Report on Carcinogens" (latest edition)	
(d)(4)(ii) International Agency for Research on Cancer (IARC) "Monographs" (latest editions)	

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Hazard Determination/Classification

Comparison

A significant difference between the HCS and GHS is the evaluation of mixtures. The GHS criteria for mixtures vary by hazard class. See individual endpoints for details. The HCS allows test data on mixtures to be used for all hazard classes. The GHS allows test data on carcinogens, mutagens, and reproductive toxins on a case-by-case basis. The GHS expectation of physical test data for mixtures is another difference.

The HCS "floor" of hazardous chemicals is a difference and one that is likely helpful to small businesses. Guidance on how IARC, NTP, and OSHA carcinogens fit with the GHS cancer classification scheme could also be useful guidance.

OSHA HCS 29 CFR 1910.1200	GHS
(d)(4)(iii) 29 CFR part 1910, subpart Z, Toxic and Hazardous Substances, Occupational Safety and Health Administration (d)(5) The chemical manufacturer, importer, or employer shall determine the hazards of mixtures of chemicals as follows: (d)(5)(i) If a mixture has been tested as a whole to determine its hazards, the results of such testing shall be used to determine whether the mixture is hazardous. (d)(5)(ii) If a mixture has not been tested as a whole to determine whether the mixture is a health hazard, the mixture shall be assumed to present the same health hazards as do the components that comprise 1% (by weight or volume) or greater of the mixture, except that the mixture shall be assumed to present a carcinogenic hazard if it contains a component in concentrations of 0.1% or greater, which is considered to be a carcinogen under paragraph (d)(4) of this section.	1.3.2.4 UNCETDG/ILO Working Group on Physical Hazards The UNCETDG/ILO Working Group for Physical Hazards used a similar process to the OECD Task Force on HCL. The work involved a comparison of the major classification systems, identification of similar or identical elements, and, for the elements that were dissimilar, development of a consensus on a compromise. For physical hazards, however, the transport definitions, test methods, and classification criteria were used as a basis for the work since they were already substantially harmonized. The work proceeded through examination of the scientific basis for the criteria, gaining consensus on the test methods, data interpretation, and the criteria. For most hazard classes, the existing schemes were already in place and being used by the transport sector. On this basis, a portion of the work focused on ensuring that workplace, environment, and consumer safety issues were adequately addressed.
(d)(5)(iii) If a mixture has not been tested as a whole to determine whether the mixture is a physical hazard, the chemical manufacturer, importer, or employer may use whatever scientifically valid data are available to evaluate the physical hazard potential of the mixture.	See the individual health hazard classes for mixture considerations.

Labels

Comparison

The HCS label requirements will now have to be specified. GHS labels have pictograms, as well as specified signal words, and hazard statements. See pictogram table and label element comparison. The HCS provision for no component disclosure on labels is accommodated in the GHS. The use of transport pictograms in nontransport settings is an option, as is the use of a black border for GHS pictograms in domestic settings. See competent authority allowance discussions.

OSHA HCS 29 CFR 1910.1200	GHS
1910.1200(f) Labels and Other Forms of Warning (f)(1) The chemical manufacturer, importer, or distributor shall ensure that each container of hazardous chemicals leaving the workplace is labeled, tagged, or marked with the following information: (f)(1)(i) Identity of the hazardous chemical(s) (f)(1)(ii) Appropriate hazard warnings (f)(1)(iii) Name and address of the chemical manufacturer, importer, or other responsible party (f)(4) If the hazardous chemical is regulated by OSHA in a substance-specific health standard, the chemical manufacturer, importer, distributor, or employer shall ensure that the labels or other forms of warning used are in accordance with the requirements of that standard.	1.4.6.2 Application of standardization in the harmonized system For labels, the hazard symbols, signal words, and hazard statements have all been standardized and assigned to each of the hazard categories. These standardized elements should not be subject to variation and should appear on the GHS label as indicated in the chapters for each hazard class in this document. For safety data sheets, the chapter *Hazard Communication: Safety Data Sheets* (Chapter 1.5) provides a standardized format for the presentation of information. While precautionary information was considered for standardization, there was insufficient time to develop detailed proposals. However, there are examples of precautionary statements and pictograms in Annex 3 and it remains a goal to develop them into fully standardized label elements. 1.4.6.3 Use of nonstandardized or supplemental information 1.4.6.3.1 There are many other label elements that may appear on a label that have not been standardized in the harmonized system. Some of these clearly need to be included on the label, for example, precautionary statements. Competent authorities may require additional information, or suppliers may choose to add supplementary information on their own initiative. In order to ensure that the use of nonstandardized information does not lead to unnecessarily wide variation in information or undermine GHS information, the use of supplementary information should be limited to the following circumstances: a. The supplementary information provides further detail and does not contradict or cast doubt on the validity of the standardized hazard information. b. The supplementary information provides information about hazards not yet incorporated into the GHS.

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Labels

Comparison

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OSHA HCS 29 CFR 1910.1200	GHS
(f)(6) The employer may use signs, placards, process sheets, batch tickets, operating procedures, or other such written materials in lieu of affixing labels to individual stationary process containers, as long as the alternative method identifies the containers to which it is applicable and conveys the information required by paragraph (f)(5) of this section to be on a label. The written materials shall be readily accessible to the employees in their work area throughout each work shift.	In either instance, the supplementary information should not lower standards of protection. 1.4.6.3.2 The labeler should have the option of providing supplementary information related to the hazard, such as physical state or route of exposure, with the hazard statement rather than in the supplementary information section on the label, see also paragraph 1.4.10.5.4.1. 1.4.10 Labeling Procedures 1.4.10.1 Scope The following sections describe the procedures for preparing labels in the GHS, comprising the following:
(f)(7) The employer is not required to label portable containers into which hazardous chemicals are transferred from labeled containers, and which are intended only for the immediate use of the employee who performs the transfer. For purposes of this section, drugs that are dispensed by a pharmacy to a health care provider for direct administration to a patient are exempted from labeling.	a. Allocation of label elements b. Reproduction of the symbol c. Reproduction of the hazard pictogram d. Signal words e. Hazard statements f. Precautionary statements and pictograms g. Product and supplier identification h. Multiple hazards and precedence of information i. Arrangements for presenting the GHS label elements j. Special labeling arrangements
(f)(11) Chemical manufacturers, importers, distributors, or employers who become newly aware of any significant information regarding the hazards of a chemical shall	1.4.10.2 Label elements The tables in the individual chapters for each hazard class detail the label elements (symbol, signal word, hazard statement) that have been assigned to each of the hazard categories of the GHS. Hazard categories reflect the harmonized classification criteria.

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Labels

Comparison

The HCS label requirements will now have to be specified. GHS labels have pictograms, as well as specified signal words, and hazard statements. See pictogram table and label element comparison. The HCS provision for no component disclosure on labels is accommodated in the GHS. The use of transport pictograms in nontransport settings is an option, as is the use of a black border for GHS pictograms in domestic settings. See competent authority allowance discussions.

OSHA HCS 29 CFR 1910.1200	GHS
revise the labels for the chemical within 3 months of becoming aware of the new information. Labels on containers of hazardous chemicals shipped after that time shall contain the new information. If the chemical is not currently produced or imported, the chemical manufacturer, importer, distributor, or employer shall add the information to the label before the chemical is shipped or introduced into the workplace again.	A summary of the allocation of label elements is provided in Annex 1. There are special arrangements that apply to the use of certain mixture concentrations in the GHS to take account of the information needs of different target audiences. These are further described in paragraph 1.4.10.5.4 1.4.10.5.2 *Information required on a GHS label* a. *Signal words* A signal word means a word used to indicate the relative level of severity of hazard and alert the reader to a potential hazard on the label. The signal words used in the GHS are "Danger" and "Warning." "Danger" is used for the more severe hazard categories (i.e., in the main for hazard categories 1 and 2), while "Warning" is used for the less severe. The tables in the individual chapters for each hazard class detail the signal words that have been assigned to each of the hazard categories of the GHS. b. *Hazard statements* A hazard statement means a phrase assigned to a hazard class and category that describes the nature of the hazards of a hazardous product, including, where appropriate, the degree of hazard. The tables of label elements in the individual chapters for each hazard class detail the hazard statements that have been assigned to each of the hazard categories of the GHS. c. *Precautionary statements and pictograms* A precautionary statement means a phrase (and/or pictogram) that describes recommended measures that should be taken to minimize or prevent adverse effects resulting from exposure to a hazardous product, or improper storage or handling of a hazardous product. The GHS label should include appropriate precautionary information, the choice of which is with the labeler or the competent authority.

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Labels

Comparison

The HCS label requirements will now have to be specified. GHS labels have pictograms, as well as specified signal words, and hazard statements. See pictogram table and label element comparison. The HCS provision for no component disclosure on labels is accommodated in the GHS. The use of transport pictograms in nontransport settings is an option, as is the use of a black border for GHS pictograms in domestic settings. See competent authority allowance discussions.

OSHA HCS 29 CFR 1910.1200	GHS
	Annex 3 contains examples of precautionary statements, which can be used, and also examples of precautionary pictograms, which can be used where allowed by the competent authority. d. *Product identifier* i. A product identifier should be used on a GHS label and it should match the product identifier used on the SDS. Where a substance or mixture is covered by the UN Model Regulations on the Transport of Dangerous Goods, the UN proper shipping name should also be used on the package. ii. The label for a substance should include the chemical identity of the substance. For mixtures or alloys, the label should include the chemical identities of all ingredients or alloying elements that contribute to acute toxicity, skin corrosion or serious eye damage, germ cell mutagenicity, carcinogenicity, reproductive toxicity, skin or respiratory sensitization, or Target Organ Systemic Toxicity (TOST), when these hazards appear on the label. Alternatively, the competent authority may require the inclusion of all ingredients or alloying elements that contribute to the hazard of the mixture or alloy. iii. Where a substance or mixture is supplied exclusively for workplace use, the competent authority may choose to give suppliers discretion to include chemical identities on the SDS, in lieu of including them on labels. iv. The competent authority rules for CBI take priority over the rules for product identification. This means that where an ingredient would normally be included on the label, if it meets the competent authority criteria for CBI, its identity does not have to be included on the label. e. *Supplier identification*

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Labels	
Comparison The HCS label requirements will now have to be specified. GHS labels have pictograms, as well as specified signal words, and hazard statements. See pictogram table and label element comparison. The HCS provision for no component disclosure on labels is accommodated in the GHS. The use of transport pictograms in nontransport settings is an option, as is the use of a black border for GHS pictograms in domestic settings. See competent authority allowance discussions.	
OSHA HCS 29 CFR 1910.1200	**GHS**
	1.4.10.5.4 Arrangements for presenting the GHS label elements 1.4.10.5.4.1 Location of GHS information on the label The GHS hazard pictograms, signal word, and hazard statements should be located together on the label. The competent authority may choose to provide a specified layout for the presentation of these and for the presentation of precautionary information, or allow supplier discretion. Specific guidance and examples are provided in the chapters on individual hazard classes.

Workplace Labeling	
Comparison The HCS workplace labeling option is allowed in the GHS. This option is a common practice in many US workplaces. See competent authority allowance discussion.	
OSHA HCS 29 CFR 1910.1200	**GHS**
1910.1200(f) (6)-(7) Workplace Labeling	1.4.10.5.5.1 Workplace labeling
(f)(6) The employer may use signs, placards, process sheets, batch tickets, operating procedures, or other such written materials in lieu of affixing labels to individual stationary process containers, as long as the alternative method identifies the containers to which it is applicable and conveys the information required by paragraph (f)(5) of this section to be on a label. The written materials shall be readily accessible to the employees in their work area throughout each work shift.	Products falling within the scope of the GHS will carry the GHS label at the point where they are supplied to the workplace, and that label should be maintained on the supplied container in the workplace. The GHS label or label elements should also be used for workplace containers. However, the competent authority can allow employers to use alternative means of giving workers the same information in a different written or displayed format when such a format is more appropriate to the workplace and communicates the information as effectively as the GHS label. For example, label information could be displayed in the work area, rather than on the individual containers.
(f)(7) The employer is not required to label portable containers into which hazardous chemicals are transferred from labeled containers, and which are intended only for the immediate use of the employee who performs the transfer. For purposes of this section, drugs that are dispensed by a pharmacy to a health care provider for direct administration to a patient are exempted from labeling.	Alternative means of providing workers with the information contained in GHS labels are needed usually where hazardous chemicals are transferred from an original supplier container into a workplace container or system, or where chemicals are produced in a workplace but are not packaged in containers intended for sale or supply. Chemicals that are produced in a workplace may be contained or stored in many different ways such as small samples collected for testing or analysis, piping systems including valves, process or reaction vessels, ore cars, conveyer systems, or freestanding bulk storage of solids. In batch manufacturing processes, one mixing vessel may be used to contain a number of different chemical mixtures.

Labels	
Comparison The HCS label requirements will now have to be specified. GHS labels have pictograms, as well as specified signal words, and hazard statements. See pictogram table and label element comparison. The HCS provision for no component disclosure on labels is accommodated in the GHS. The use of transport pictograms in nontransport settings is an option, as is the use of a black border for GHS pictograms in domestic settings. See competent authority allowance discussions.	
OSHA HCS 29 CFR 1910.1200	**GHS**
	In many situations, it is impractical to produce a complete GHS label and attach it to the container, due, for example, to container size limitations or lack of access to a process container. Some examples of workplace situations where chemicals may be transferred from supplier containers include containers for laboratory testing or analysis, storage vessels, piping or process reaction systems, or temporary containers where the chemical will be used by one worker within a short time frame. Decanted chemicals intended for immediate use could be labeled with the main components and directly refer the user to the supplier label information and SDS. All such systems should ensure that there is clear hazard communication. Workers should be trained to understand the specific communication methods used in a workplace. Examples of alternative methods include use of product identifiers together with GHS symbols and other pictograms to describe precautionary measures; use of process flow charts for complex systems to identify chemicals contained in pipes and vessels with links to the appropriate SDS; use of displays with GHS symbols, color, and signal words in piping systems and processing equipment; use of permanent placarding for fixed piping; use of batch tickets or recipes for labeling batch mixing vessels; and use of piping bands with hazard symbols and product identifiers.

Updating Labels

Comparison

The current HCS requirements for updating labels are accommodated by the GHS. Other options could be considered for the purpose of harmonization. See competent authority allowances discussion.

OSHA HCS 29 CFR 1910.1200	GHS
1910.1200(f)(11) Updating Labels **(f)(11)** Chemical manufacturers, importers, distributors, or employers who become newly aware of any significant information regarding the hazards of a chemical shall revise the labels for the chemical within 3 months of becoming aware of the new information. Labels on containers of hazardous chemicals shipped after that time shall contain the new information. If the chemical is not currently produced or imported, the chemical manufacturer, importer, distributor, or employer shall add the information to the label before the chemical is shipped or introduced into the workplace again.	**1.4.7 updating information** All systems should specify a means of responding in an appropriate and timely manner to new information and updating labels and SDS information accordingly. The following are examples of how this could be achieved. 1.4.7.2 General guidance on updating of information 1.4.7.2.1 Suppliers should respond to "new and significant" information they receive about a chemical hazard by updating the label and safety data sheet for that chemical. New and significant information is any information that changes the GHS classification of the substance or mixture and leads to a resulting change in the information provided on the label or any information concerning the chemical and appropriate control measures that may affect the SDS. This could include, for example, new information on the potential adverse chronic health effects of exposure as a result of recently published documentation or test results, even if a change in classification may not yet be triggered. 1.4.7.2.2 Updating should be carried out promptly on receipt of the information that necessitates the revision. The competent authority may choose to specify a time limit within which the information should be revised. This applies only to labels and SDS for products that are not subject to an approval mechanism such as pesticides. In pesticide labeling systems, where the label is part of the product approval mechanism, suppliers cannot update the supply label on their own initiative. However, when the products are subject to the transport of dangerous goods requirements, the label used should be updated on receipt of the new information, as above. 1.4.7.2.3 Suppliers should also periodically review the information on which the label and safety data sheet for a substance or mixture are based, even if no new and significant information has been provided to them in respect of that substance or mixture. This will require, for example, a search of chemical hazard databases for new information. The competent authority may choose to specify a time (typically 3–5 years) from the date of original preparation, within which suppliers should review the labels and SDS information.

Comparison

The performance orientation of the HCS MSDS will need to be changed. The GHS requires a 16-section MSDS format with specified sequence and minimum required contents. See separate table for more detailed comparison of MSDS sections/information.

On the basis of requirements in existing systems, there is some discretion in the GHS for determining when an MSDS is required. The hazard pictogram/symbol can be graphically reproduced on the MSDS or the name of the symbol may be provided instead. The level of hazardous components can be given as ranges or concentrations.

OSHA HCS 29 CFR 1910.1200	**GHS**
1910.1200(g) MSDS (g)(2) Each material safety data sheet shall be in English (although the employer may maintain copies in other languages as well) and shall contain at least the following information: (g)(2)(i) The identity used on the label, and, except as provided for in paragraph (i) of this section on trade secrets: (g)(2)(i)(A) If the hazardous chemical is a single substance, its chemical and common name(s) (g)(2)(i)(B) If the hazardous chemical is a mixture that has been tested as a whole to determine its hazards, the chemical and common name(s) of the ingredients that contribute to these known hazards and the common name(s) of the mixture itself (g)(2)(i)(C) If the hazardous chemical is a mixture that has not been tested as a whole:	Table 1.5.2 Minimum information for an SDS 1. *Product and company identification* • GHS product identifier • Other means of identification • Recommended use of the chemical and restrictions on use • Supplier's details (including name, address, phone number, etc). • Emergency phone number 2. *Hazards identification* • GHS classification of the substance/mixture and any regional information • GHS label elements, including precautionary statements (Hazard symbols may be provided as a graphical reproduction of the symbols in black and white or the name of the symbol, e.g., flame, skull, and crossbones.) • Other hazards that do not result in classification (e.g., dust explosion hazard) or are not covered by the GHS 3. *Composition/information on ingredients* Substance • Chemical identity • Common name, synonyms, and so on • CAS number, EC number, and so on • Impurities and stabilizing additives that are themselves classified and that contribute to the classification of the substance • Mixture • The chemical identity and concentration or concentration ranges of all ingredients that are hazardous within the meaning of the GHS and are present above their cutoff levels.

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OSHA HCS 29 CFR 1910.1200	GHS
(g)(2)(i)(C)(1) The chemical and common name(s) of all ingredients which have been determined to be health hazards, and which comprise 1% or greater of the composition, except that chemicals identified as carcinogens under paragraph (d) of this section shall be listed if the concentrations are 0.1% or greater (g)(2)(i)(C)(2) The chemical and common name(s) of all ingredients that have been determined to be health hazards and that comprise less than 1% (0.1% for carcinogens) of the mixture, if there is evidence that the ingredient(s) could be released from the mixture in concentrations that would exceed an established OSHA permissible exposure limit or ACGIH Threshold Limit Value, or could present a health risk to employees (g)(2)(i)(C)(3) The chemical and common name(s) of all ingredients that have been determined to present a physical hazard when present in the mixture (g)(2)(ii) Physical and chemical characteristics of the hazardous chemical (such as vapor pressure, flash point)	• Cutoff level for reproductive toxicity, carcinogenicity, and category 1 mutagenicity is ≥0.1%. • Cutoff level for all other hazard classes is ≥1%. *Note: For information on ingredients, the competent authority rules for CBI take priority over the rules for product identification.* 4. *First-aid measures* • Description of necessary measures, subdivided according to the different routes of exposure, that is, inhalation, skin and eye contact, and ingestion • Most important symptoms/effects, acute and delayed • Indication of immediate medical attention and special treatment needed, if necessary 5. *Fire-fighting measures* • Suitable (and unsuitable) extinguishing media • Specific hazards arising from the chemical (e.g., nature of any hazardous combustion products) • Special protective equipment and precautions for firefighters 6. *Accidental release Pleasures* • Personal precautions, protective equipment, and emergency procedures • Environmental precautions • Methods and materials for containment and cleaning up 7. *Handling and storage* • Precautions for safe handling • Conditions for safe storage, including any incompatibilities

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Comparison

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On the basis of requirements in existing systems, there is some discretion in the GHS for determining when an MSDS is required. The hazard pictogram/symbol can be graphically reproduced on the MSDS or the name of the symbol may be provided instead. The level of hazardous components can be given as ranges or concentrations.

OSHA HCS 29 CFR 1910.1200	GHS
(g)(2)(iii) The physical hazards of the hazardous chemical, including the potential for fire, explosion, and reactivity	8. *Exposure controls/personal protection* • Control parameters, for example, occupational exposure limit values or biological limit values • Appropriate engineering controls • Individual protection measures, such as personal protective equipment
(g)(2)(iv) The health hazards of the hazardous chemical, including signs and symptoms of exposure, and any medical conditions that are generally recognized as being aggravated by exposure to the chemical	9. *Physical and chemical properties* • Appearance (physical state, color, etc.) • Odor • Odor threshold • pH • Melting point/freezing point • Initial boiling point and boiling range • Flash point • Evaporation rate • Flammability (solid, gas) • Upper/lower flammability or explosive limits • Vapor pressure • Vapor density • Relative density • Solubility(ies) • Partition coefficient: n-octanol/water • Auto-ignition temperature decomposition temperature
(g)(2)(v) The primary route(s) of entry	
(g)(2)(vi) The OSHA permissible exposure limit, ACGIH Threshold Limit Value, and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the material safety data sheet, where available	
(g)(2)(vii) Whether the hazardous chemical is listed in the National Toxicology Program (NTP) Annual Report on Carcinogens (latest edition) or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions), or by OSHA	

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MSDS/SDS

Comparison

The performance orientation of the HCS MSDS will need to be changed. The GHS requires a 16-section MSDS format with specified sequence and minimum required contents. See separate table for more detailed comparison of MSDS sections/information.

On the basis of requirements in existing systems, there is some discretion in the GHS for determining when an MSDS is required. The hazard pictogram/symbol can be graphically reproduced on the MSDS or the name of the symbol may be provided instead. The level of hazardous components can be given as ranges or concentrations.

OSHA HCS 29 CFR 1910.1200	GHS
(g)(2)(viii) Any generally applicable precautions for safe handling and use that are known to the chemical manufacturer, importer, or employer preparing the material safety data sheet, including appropriate hygienic practices, protective measures during repair and maintenance of contaminated equipment, and procedures for cleanup of spills and leaks	10. *Stability and reactivity—chemical stability* • Possibility of hazardous reactions • Conditions to avoid (e.g., static discharge, shock, or vibration) • Incompatible materials • Hazardous decomposition products
(g)(2)(ix) Any generally applicable control measures that are known to the chemical manufacturer, importer, or employer preparing the material safety data sheet, such as appropriate engineering controls, work practices, or personal protective equipment	11. *Toxicological information* Concise but complete and comprehensible description of the various toxicological (health) effects and the available data used to identify those effects, including • Information on the likely routes of exposure (inhalation, ingestion, skin, and eye contact) • Symptoms related to the physical, chemical, and toxicological characteristics • Delayed and immediate effects and also chronic effects from short- and long-term exposure • Numerical measures of toxicity (such as acute toxicity estimates)
(g)(2)(x) Emergency and first-aid procedures	12. *Ecological information* • Ecotoxicity (aquatic and terrestrial, where available) • Persistence and degradability • Bioaccumulative potential • Mobility in soil • Other adverse effects
(g)(2)(xi) The date of preparation of the material safety data sheet or the last change to it	13. *Disposal considerations* • Description of waste residues and information on their safe handling and methods of disposal, including any contaminated packaging
(g)(2)(xii) The name, address, and telephone number of the chemical manufacturer, importer, employer, or other responsible party preparing or distributing the material safety data sheet, who can provide additional information on the hazardous chemical and appropriate emergency procedures, if necessary	

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Comparison

The performance orientation of the HCS MSDS will need to be changed. The GHS requires a 16-section MSDS format with specified sequence and minimum required contents. See separate table for more detailed comparison of MSDS sections/information.

On the basis of requirements in existing systems, there is some discretion in the GHS for determining when an MSDS is required. The hazard pictogram/symbol can be graphically reproduced on the MSDS or the name of the symbol may be provided instead. The level of hazardous components can be given as ranges or concentrations.

OSHA HCS 29 CFR 1910.1200	GHS
(g)(3) If no relevant information is found for any given category on the material safety data sheet, the chemical manufacturer, importer, or employer preparing the material safety data sheet shall mark it to indicate that no applicable information was found.	14. *Transport information* • UN number • UN Proper shipping name • Transport hazard class(es) • Packing group, if applicable • Marine pollutant (yes / no) • Special precautions that a user needs to be aware of or needs to comply with in connection with transport or conveyance either within or outside their premises 15. *Regulatory information* • Safety, health, and environmental regulations specific for the product in question 16. *Other information* • Other information including information the on preparation and revision of the SDS
(g)(5) [MSDS Updating] The chemical manufacturer, importer, or employer preparing the material safety data sheet shall ensure that the information recorded accurately reflects the scientific evidence used in making the hazard determination. If the chemical manufacturer, importer, or employer preparing the material safety data sheet becomes newly aware of any significant information regarding the hazards of a chemical, or ways to protect against the hazards, this new information shall be added to the material safety data sheet within 3 months. If the chemical is not currently being produced or imported, the chemical manufacturer or importer shall add the information to the material safety data sheet before the chemical is introduced into the workplace again.	1.5.2 Criteria for determining whether an SDS should be produced An SDS should be produced for all substances and mixtures that meet the harmonized criteria for physical, health, or environmental hazards under the GHS and for all mixtures that contain substances that meet the criteria for carcinogenic, toxic to reproduction, or target organ systemic toxicity in concentrations exceeding the cutoff limits for SDS specified by the criteria for mixtures (see paragraph 6). The competent authority may choose also to require SDSs for mixtures not meeting the criteria for classification as hazardous but which contain hazardous substances in certain concentrations (see paragraph 6).
(g)(10) [MSDS Format] Material safety data sheets may be kept in any form, including operating procedures, and may be designed to cover groups of hazardous chemicals in a work area where it may be more	

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MSDS/SDS	
Comparison The performance orientation of the HCS MSDS will need to be changed. The GHS requires a 16-section MSDS format with specified sequence and minimum required contents. See separate table for more detailed comparison of MSDS sections/information. On the basis of requirements in existing systems, there is some discretion in the GHS for determining when an MSDS is required. The hazard pictogram/symbol can be graphically reproduced on the MSDS or the name of the symbol may be provided instead. The level of hazardous components can be given as ranges or concentrations.	
OSHA HCS 29 CFR 1910.1200	**GHS**
appropriate to address the hazards of a process rather than individual hazardous chemicals. However, the employer shall ensure that in all cases, the required information is provided for each hazardous chemical and is readily accessible during each work shift to employees when they are in their work area(s).	An SDS should be provided on the basis of the following generic cutoff/concentration limits: ≥1% for acute toxicity, skin corrosion/irritation, serious damage to eyes/eye irritation, respiratory/skin sensitization, mutagenicity category 2, target organ toxicity (single and repeat) exposures, and hazardous to the environment • ≥ 0.1% for mutagenicity category 1, carcinogenicity, and reproductive toxicity As noted in the *Classification of Hazardous Substances and Mixtures* (Chapter 1.2, paragraphs 28 through 31), there may be some cases when the available hazard data may justify classification on the basis of other cutoff limits than the generic ones specified in the health and environment hazard class chapters (Chapters 3.2 through 3.10). When such specific cutoffs are used for classification, they should also apply to the obligation to compile an SDS. Some competent authorities (CA) may require SDSs to be compiled for mixtures that are not classified for acute toxicity or aquatic toxicity as a result of application of the additivity formula, but which contain acutely toxic substances or substances toxic to the aquatic environment in concentrations equal to or greater than 1%. In accordance with the building block principle, some competent authorities may choose not to regulate certain categories within a hazard class. In such situations, there would be no obligation to compile an SDS. (*The above four paragraphs are not part of the agreed text on hazard communication including SDSs developed by the ILO Working Group on Hazard Communication but have been provided here as additional guidance on the compiling of an SDS.)* Once it is clear that an SDS is required for a substance or a mixture, then the information required to be included in the SDS should in all cases be provided in accordance with GHS requirements.

MSDS/SDS Component Disclosure

Comparison

The values for component disclosure in mixtures vary by endpoint. Some changes will be required on MSDS component disclosure. The level of hazardous components can be given as ranges or concentrations in the MSDS.

OSHA HCS 29 CFR 1910.1200	GHS
(g)(2)(i) The identity used on the label, and, except as provided for in paragraph (i) of this section on trade secrets:	Table 1.5.2 Minimum information for an SDS3 Composition/information on ingredients
(g)(2)(i)(A) If the hazardous chemical is a single substance, its chemical and common name(s)	Substance • Chemical identity • Common name, synonyms, and so on • CAS number, EC number, and so on • Impurities and stabilizing additives that are themselves classified and that contribute to the classification of the substance
(g)(2)(i)(B) If the hazardous chemical is a mixture that has been tested as a whole to determine its hazards, the chemical and common name(s) of the ingredients that contribute to these known hazards, and the common name(s) of the mixture itself	Mixture • The chemical identity and concentration or concentration ranges of all ingredients that are hazardous within the meaning of the GHS and are present above their cutoff levels
(g)(2)(i)(C) If the hazardous chemical is a mixture that has not been tested as a whole:	*Note: For information on ingredients, the competent authority rules for CBI take priority over the rules for product identification.*
(g)(2)(i)(C)(1) The chemical and common name(s) of all ingredients that have been determined to be health hazards and that comprise 1% or greater of the composition, except that chemicals identified as carcinogens under paragraph (d) of this section shall be listed if the concentrations are 0.1% or greater	**1.5.2 Criteria for determining whether an SDS should be produced** An SDS should be produced for all substances and mixtures that meet the harmonized criteria for physical, health, or environmental hazards under the GHS and for all mixtures that contain substances that meet the criteria for carcinogenic, toxic to reproduction, or target organ systemic toxicity in concentrations exceeding the cutoff limits for SDS specified by the criteria for mixtures (see paragraph 1.5.3.1). The competent authority may choose also to require SDSs for mixtures not meeting the criteria for classification as hazardous but which contain hazardous substances in certain concentrations (see paragraph 1.5.3.1).
(g)(2)(i)(C)(2) The chemical and common name(s) of all ingredients that have been determined to be health hazards and that comprise less than 1% (0.1% for carcinogens) of the mixture, if there is evidence that the ingredient(s)	1.5.3 General guidance for compiling a safety data sheet 1.5.3.1 Cutoff values/concentration limits 1.5.3.1.1 An SDS should be provided on the basis of the generic cutoff values/concentration limit

(*Continued*)

MSDS/SDS Component Disclosure

Comparison

The values for component disclosure in mixtures vary by endpoint. Some changes will be required on MSDS component disclosure. The level of hazardous components can be given as ranges or concentrations in the MSDS.

OSHA HCS 29 CFR 1910.1200	GHS
could be released from the mixture in concentrations that would exceed an established OSHA permissible exposure limit or ACGIH Threshold Limit Value, or could present a health risk to employees	≥1% for acute toxicity, skin corrosion/irritation, serious damage to eyes/eye irritation, respiratory/skin sensitization, mutagenicity category 2, target organ toxicity (single and repeat) exposures, and hazardous to the environment. ≥0.1% for mutagenicity category 1, carcinogenicity, and reproductive toxicity (sensitizes).
(g)(2)(i)(C)(3) The chemical and common name(s) of all ingredients that have been determined to present a physical hazard when present in the mixture	1.5.3.1.2 As noted in the *Classification of Hazardous Substances and Mixtures* (see 1.3.3.2), there may be some cases when the available hazard data may justify classification on the basis of other cutoff values/concentration limits than the generic ones specified in the health and environment hazard class chapters (Chapters 3.2 through 3.10). When such specific cutoff values are used for classification, they should also apply to the obligation to compile an SDS. 1.5.3.1.3 Some competent authorities (CA) may require SDSs to be compiled for mixtures that are not classified for acute toxicity or aquatic toxicity as a result of application of the additivity formula but that contain acutely toxic substances or substances toxic to the aquatic environment in concentrations equal to or greater than 1%. 1.5.3.1.4 In accordance with the building block principle, some competent authorities may choose not to regulate certain categories within a hazard class. In such situations, there would be no obligation to compile an SDS. *(Paragraphs 1.5.3.1.1 through 1.5.3.1.4 are not part of the agreed text on hazard communication including SDSs developed by the ILO Working Group on Hazard Communication but have been provided here as additional guidance on the compiling of an SDS.)* 1.5.3.1.5 Once it is clear that an SDS is required for a substance or a mixture, then the information required to be included in the SDS should in all cases be provided in accordance with GHS requirements.

Updating MSDS/SDS

Comparison

The current HCS requirements for updating MSDS are accommodated by the GHS. Other options could be considered for the purpose of harmonization.

OSHA HCS 29 CFR 1910.1200	GHS
1910.1200(g)(5) updating MSDS **(g)(5) [MSDS Updating]** The chemical manufacturer, importer, or employer preparing the material safety data sheet shall ensure that the information recorded accurately reflects the scientific evidence used in making the hazard determination. If the chemical manufacturer, importer, or employer preparing the material safety data sheet becomes newly aware of any significant information regarding the hazards of a chemical, or ways to protect against the hazards, this new information shall be added to the material safety data sheet within 3 months. If the chemical is not currently being produced or imported, the chemical manufacturer or importer shall add the information to the material safety data sheet before the chemical is introduced into the workplace again.	**1.4.7 Updating information** All systems should specify a means of responding in an appropriate and timely manner to new information and updating labels and SDS information accordingly. The following are examples of how this could be achieved. 1.4.7.2 General guidance on updating of information 1.4.7.2.1 Suppliers should respond to "new and significant" information they receive about a chemical hazard by updating the label and safety data sheet for that chemical. New and significant information is any information that changes the GHS classification of the substance or mixture and leads to a resulting change in the information provided on the label or any information concerning the chemical and appropriate control measures that may affect the SDS. This could include, for example, new information on the potential adverse chronic health effects of exposure as a result of recently published documentation or test results, even if a change in classification may not yet be triggered. 1.4.7.2.2 Updating should be carried out promptly on receipt of the information that necessitates the revision. The competent authority may choose to specify a time limit within which the information should be revised. This applies only to labels and SDS for products that are not subject to an approval mechanism such as pesticides. In pesticide labeling systems, where the label is part of the product approval mechanism, suppliers cannot update the supply label on their own initiative. However, when the products are subject to the transport of dangerous goods requirements, the label used should be updated on receipt of the new information, as above. 1.4.7.2.3 Suppliers should also periodically review the information on which the label and safety data sheet for a substance or mixture are based, even if no new and significant information has been provided to them in respect of that substance or mixture. This will require, for example, a search of chemical hazard databases for new information. The competent authority may choose to specify a time (typically 3–5 years) from the date of original preparation, within which suppliers should review the labels and SDS information.

Information and Training

Comparison
The GHS has broad general training requirements. The HCS has more detailed training requirements than the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
(h) "Employee information and training." **(h)(1)** Employers shall provide employees with effective information and training on hazardous chemicals in their work area at the time of their initial assignment and whenever a new physical or health hazard the employees have not previously been trained about is introduced into their work area. Information and training may be designed to cover categories of hazards (e.g., flammability, carcinogenicity) or specific chemicals. Chemical-specific information must always be available through labels and material safety data sheets. **(h)(2)** "Information." Employees shall be informed of: **(h)(2)(i)** The requirements of this section **(h)(2)(ii)** Any operations in their work area where hazardous chemicals are present **(h)(2)(iii)** The location and availability of the written hazard communication program, including the required list(s) of hazardous chemicals, and material safety data sheets required by this section	**1.4.9 Training** Training users of hazard information is an integral part of hazard communication. Systems should identify the appropriate education and training for GHS target audiences who are required to interpret label and/or SDS information and to take appropriate action in response to chemical hazards. Training requirements should be appropriate for and commensurate with the nature of the work or exposure. Key target audiences for training include workers, emergency responders, and those involved in the preparation of labels, SDS, and hazard communication strategies as part of risk management systems. Others involved in the transport and supply of hazardous chemicals also require training to varying degrees. In addition, systems should consider strategies required for educating consumers in interpreting label information on products that they use.

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Information and Training

Comparison
The GHS has broad general training requirements. The HCS has more detailed training requirements than the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
(h)(3) "Training." Employee training shall include at least:	
(h)(3)(i) Methods and observations that may be used to detect the presence or release of a hazardous chemical in the work area (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.)	
(h)(3)(ii) The physical and health hazards of the chemicals in the work area	
(h)(3)(iii) The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used	
(h)(3)(iv) The details of the hazard communication program developed by the employer, including an explanation of the labeling system and the material safety data sheet, and how employees can obtain and use the appropriate hazard information	

Trade Secrets/CBI

Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
(i) "Trade secrets." (i)(1) Chemical name and other specific identification of a hazardous chemical, from the material safety data sheet, provided that: **(i)(1)(i)** The claim that the information withheld is a trade secret can be supported **(i)(1)(ii)** Information contained in the material safety data sheet concerning the properties and effects of the hazardous chemical is disclosed **(i)(1)(iii)** The material safety data sheet indicates that the specific chemical identity is being withheld as a trade secret **(i)(1)(iv)** The specific chemical identity is made available to health professionals, employees, and designated representatives in accordance with the applicable provisions of this paragraph	**1.4.8 Confidential business information** 1.4.8.1 Systems adopting the GHS should consider what provisions may be appropriate for the protection of confidential business information (CBI). Such provisions should not compromise the health and safety of workers or consumers, or the protection of the environment. As with other parts of the GHS, the rules of the importing country should apply with respect to CBI claims for imported substances and mixtures. 1.4.8.2 Where a system chooses to provide for protection of confidential business information, competent authorities should establish appropriate mechanisms, in accordance with national law and practice, and consider a. Whether the inclusion of certain chemicals or classes of chemicals in the arrangements is appropriate to the needs of the system b. What definition of "confidential business information" should apply, taking account of factors such as the accessibility of the information by competitors, intellectual property rights, and the potential harm disclosure would cause to the employer or supplier's business c. Appropriate procedures for the disclosure of confidential business information, where necessary to protect the health and safety of workers or consumers, or to protect the environment, and measures to prevent further disclosure

(*Continued*)

Trade Secrets/CBI

Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
(i)(2) Where a treating physician or nurse determines that a medical emergency exists and the specific chemical identity of a hazardous chemical is necessary for emergency or first-aid treatment, the chemical manufacturer, importer, or employer shall immediately disclose the specific chemical identity of a trade secret chemical to that treating physician or nurse, regardless of the existence of a written statement of need or a confidentiality agreement. The chemical manufacturer, importer, or employer may require a written statement of need and confidentiality agreement, in accordance with the provisions of paragraphs (i)(3) and (4) of this section, as soon as circumstances permit. **(i)(3)** In nonemergency situations, a chemical manufacturer, importer, or employer shall, upon request, disclose a specific chemical identity, otherwise permitted to be withheld under paragraph (i)(l) of this section, to a health professional (i.e., physician, industrial hygienist, toxicologist, epidemiologist, or occupational health nurse) providing medical or other occupational health services to exposed employee(s), and to employees or designated representatives, if: **(i)(3)(i)** The request is in writing **(i)(3)(ii)** The request describes with reasonable detail one or more of the following occupational health needs for the information:	1.4.8.3 Specific provisions for the protection of confidential business information may differ among systems in accordance with national law and practice. However, they should be consistent with the following general principles: a. For information otherwise required on labels or safety data sheets, CBI claims should be limited to the names of chemicals and their concentrations in mixtures. All other information should be disclosed on the label or safety data sheet, as required. b. Where CBI has been withheld, the label or chemical safety data sheet should so indicate. c. CBI should be disclosed to the competent authority upon request. The competent authority should protect the confidentiality of the information in accordance with applicable law and practice. d. Where a medical professional determines that a medical emergency exists due to exposure to a hazardous chemical or a chemical mixture, mechanisms should be in place to ensure timely disclosure by the supplier or employer or competent authority of any specific confidential information necessary for treatment. The medical professional should maintain the confidentiality of the information. e. For nonemergency situations, the supplier or employer should ensure disclosure of confidential information to a safety or health professional providing medical or other safety and health services to exposed workers or consumers, and to workers or workers' representatives. Persons requesting the information should provide specific reasons for the disclosure and should agree to use the information only for the purpose of consumer or worker protection, and to otherwise maintain its confidentiality.

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Trade Secrets/CBI

Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
(i)(3)(ii)(A) To assess the hazards of the chemicals to which employees will be exposed **(i)(3)(ii)(B)** To conduct or assess sampling of the workplace atmosphere to determine employee exposure levels **(i)(3)(ii)(C)** To conduct preassignment or periodic medical surveillance of exposed employees **(i)(3)(ii)(D)** To provide medical treatment to exposed employees **(i)(3)(ii)(E)** To select or assess appropriate personal protective equipment for exposed employees **(i)(3)(ii)(F)** To design or assess engineering controls or other protective measures for exposed employees **(i)(3)(ii)(G)** To conduct studies to determine the health effects of exposure	f. Where nondisclosure of CBI is challenged, the competent authority should address such challenges or provide for an alternative process for challenges. The supplier or employer should be responsible for supporting the assertion that the withheld information qualifies for CBI protection.

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Trade Secrets/CBI

Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
(i)(3)(iii) The request explains in detail why the disclosure of the specific chemical identity is essential and that, in lieu thereof, the disclosure of the following information to the health professional, employee, or designated representative would not satisfy the purposes described in paragraph (i)(3)(ii) of this section:	
(i)(3)(iii)(A) The properties and effects of the chemical	
(i)(3)(iii)(B) Measures for controlling workers' exposure to the chemical	
(i)(3)(iii)(C) Methods of monitoring and analyzing worker exposure to the chemical	
(i)(3)(iii)(D) Methods of diagnosing and treating harmful exposures to the chemical	
(i)(3)(iv) The request includes a description of the procedures to be used to maintain the confidentiality of the disclosed information.	
(i)(3)(v) The health professional and the employer or contractor of the services of the health professional (i.e., downstream employer, labor organization, or individual employee), employee, or designated representative agree in a written confidentiality agreement that the health professional, employee, or designated representative will not use the trade secret	

(*Continued*)

Trade Secrets/CBI

Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
information for any purpose other than the health need(s) asserted and agree not to release the information under any circumstances other than to OSHA, as provided in paragraph (i)(6) of this section, except as authorized by the terms of the agreement or by the chemical manufacturer, importer, or employer.	
(i)(4) The confidentiality agreement authorized by paragraph (i)(3)(iv) of this section	
(i)(4)(i) May restrict the use of the information to the health purposes indicated in the written statement of need	
(i)(4)(ii) May provide for appropriate legal remedies in the event of a breach of the agreement, including stipulation of a reasonable pre-estimate of likely damages	
(i)(4)(iii) May not include requirements for the posting of a penalty bond	
(i)(5) Nothing in this standard is meant to preclude the parties from pursuing non-contractual remedies to the extent permitted by law.	

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Trade Secrets/CBI

Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
(i)(6) If the health professional, employee, or designated representative receiving the trade secret information decides that there is a need to disclose it to OSHA, the chemical manufacturer, importer, or employer who provided the limitations or conditions upon the disclosure of the requested chemical information as may be appropriate to assure that the occupational health services are provided without an undue risk of harm to the chemical manufacturer, importer, or employer.	
(i)(11) If a citation for a failure to release specific chemical identity information is contested by the chemical manufacturer, importer, or employer, the matter will be adjudicated before the Occupational Safety and Health Review Commission in accordance with the Act's enforcement scheme and the applicable Commission rules of procedure. In accordance with the Commission rules, when a chemical manufacturer, importer, or employer continues to withhold the information during the contest, the Administrative Law Judge may review the citation and supporting documentation "in camera" or issue appropriate orders to protect the confidentiality of such matters.	
(i)(12) Notwithstanding the existence of a trade secret claim, a chemical manufacturer, importer, or employer shall, upon request, disclose to the Assistant Secretary any information that this section requires the chemical manufacturer, importer, or employer to make available. Where there is a trade secret claim, such claim shall be made no later than at the	

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Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
time the information is provided to the Assistant Secretary so that suitable determinations of trade secret status can be made and the necessary protections can be implemented.	
(i)(13)	
Nothing in this paragraph shall be construed as requiring the disclosure under any circumstances of process or percentage of mixture information that is a trade secret.	
Appendix D Definition of Trade Secret (Mandatory)	
The following is a reprint of the "Restatement of Torts" section 757, comment b (1939):	
b. "Definition of trade secret." A trade secret may consist of any formula, pattern, device or compilation of information which is used in one's business, and which gives him an opportunity to obtain an advantage over competitors who do not know or use it. It may be a formula for a chemical compound, a process of manufacturing, treating or preserving materials, a pattern for a machine or other device, or a list of customers. It differs from other secret information in a business (see s759 of the Restatement of Torts which is not included in this Appendix) in that it is not simply information as to single or ephemeral events in the conduct of the business, as, for example, the amount or other terms of a secret bid for a contract or the salary of certain employees, or the security investments made or contemplated, or the date fixed for the announcement of a new policy or for bringing out a new model or the like. A trade secret is a process or device for continuous use in the operations of the business. Generally it relates to the production of	

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Comparison

The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
goods, as, for example, a machine or formula for the production of an article. It may, however, relate to the sale of goods or to other operations in the business, such as a code for determining discounts, rebates or other concessions in a price list or catalog, or a list of specialized customers, or a method of bookkeeping or other office management. "Secrecy." The subject matter of a trade secret must be secret. Matters of public knowledge or of general knowledge in an industry cannot be appropriated by one as his secret. Matters which are completely disclosed by the goods which one markets cannot be his secret. Substantially, a trade secret is known only in the particular business in which it is used. It is not requisite that only the proprietor of the business knows it. He may, without losing his protection, communicate it to employees involved in its use. He may likewise communicate it to others pledged to secrecy. Others may also know of it independently, as, for example, when they have discovered the process or formula by independent invention and are keeping it secret. Nevertheless, a substantial element of secrecy must exist, so that, except by the use of improper means, there would be difficulty in acquiring the information. An exact definition of a trade secret is not possible. Some factors to be considered in determining whether given information is one's trade secret are: (1) the extent to which the information is known outside of his business; (2) the extent to which it is known by employees and others involved in his business; (3) the extent of measures taken by him to guard the secrecy of the information; (4) the value of the information to him and his competitors; (5) the amount of effort or money expended by him in developing the information; (6) the ease or difficulty with which the information could be properly acquired or duplicated by others.	

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Trade Secrets/CBI	
Comparison The GHS provides CBI principles and guidance. The GHS does not harmonize CBI requirements. The HCS is aligned with the CBI principles in the GHS.	
OSHA HCS 29 CFR 1910.1200	**GHS**
"Novelty and prior art." A trade secret may be a device or process which is patentable; but it need not be that. It may be a device or process which is clearly anticipated in the prior art or one which is merely a mechanical improvement that a good mechanic can make. Novelty and invention are not requisite for a trade secret as they are for patentability. These requirements are essential to patentability because a patent protects against unlicensed use of the patented device or process even by one who discovers it properly through independent research. The patent monopoly is a reward to the inventor. But such is not the case with a trade secret. Its protection is not based on a policy of rewarding or otherwise encouraging the development of secret processes or devices.	
The protection is merely against breach of faith and reprehensible means of learning another's secret. For this limited protection, it is not appropriate to require also the kind of novelty and invention which is a requisite of patentability. The nature of the secret is, however, an important factor in determining the kind of relief that is appropriate against one who is subject to liability under the rule stated in this section. Thus, if the secret consists of a device or process which is a novel invention, one who acquires the secret wrongfully is ordinarily enjoined from further use of it and is required to account for the profits derived from his past use. If, on the other hand, the secret consists of mechanical improvements that a good mechanic can make without resort to the secret, the wrongdoer's liability may be limited to damages, and an injunction against future use of the improvements made with the aid of the secret may be inappropriate.	

Comparison

The HCS will need to consider label requirements for multiple hazards with prescribed pictograms and statements. Are all elements required? Is there a precedence? See competent authority allowances discussions.

OSHA HCS 29 CFR 1910.1200	GHS
Multiple hazards CPL2-2.38D, Appendix A The label is intended to be an immediate visual reminder of the hazards of a chemical. It is not necessary, however, that every hazard presented by a chemical be listed on the label. Manufacturers, importers, and distributors will have to assess the evidence regarding the product's hazards and must consider exposures under normal circumstances of use or foreseeable emergencies when evaluating what hazards to put on the label. This is not to say that only acute hazards are to be listed on the label or that well-substantiated hazards should be left off the label because they appear on the data sheet.	1.4.10.5.3 Multiple hazards and precedence of hazard information The following arrangements apply where a substance or mixture presents more than one GHS hazard. It is without prejudice to the building block principle described in the *Purpose, Scope and Application* (Chapter 1.1). Therefore, where a system does not provide information on the label for a particular hazard, the application of the arrangements should be modified accordingly. 1.4.10.5.3.1 Precedence for the allocation of symbols For substances and mixtures covered by the UN Recommendations on the Transport of Dangerous Goods, Model Regulations, the precedence of symbols for physical hazards should follow the rules of the UN Model Regulations. In workplace situations, the competent authority may require all symbols for physical hazards to be used. For health hazards, the following principles of precedence apply: (a) If the skull and crossbones applies, the exclamation mark should not appear. (b) If the corrosive symbol applies, the exclamation mark should not appear where it is used for skin or eye irritation. (c) If the new health hazard symbol appears for respiratory sensitization, the exclamation mark should not appear where it is used for skin sensitization or for skin or eye irritation. 1.4.10.5.3.2 Precedence for allocation of signal words If the signal word "Danger" applies, the signal word "Warning" should not appear. 1.4.10.5.3.3 Precedence for allocation of hazard statements All assigned hazard statements should appear on the label. The competent authority may choose to specify the order in which they appear.

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Multiple Hazards/Precedence

Comparison

The HCS will need to consider label requirements for multiple hazards with prescribed pictograms and statements. Are all elements required? Is there a precedence? See competent authority allowances discussions.

OSHA HCS 29 CFR 1910.1200	GHS
	1.4.10.5.4 Arrangements for presenting the GHS label elements 1.4.10.5.4.1 Location of GHS information on the label The GHS hazard pictograms, signal word, and hazard statements should be located together on the label. The competent authority may choose to provide a specified layout for the presentation of these and for the presentation of precautionary information, or allow supplier discretion. Specific guidance and examples are provided in the chapters on individual hazard classes. There have been some concerns about how the label elements should appear on different packagings. Specific examples are provided in Annex 6. 1.4.10.5.4.2 Supplemental information The competent authority has the discretion to allow the use of supplemental information subject to the parameters outlined in 1.4.6.3. The competent authority may choose to specify where this information should appear on the label or allow supplier discretion. In either approach, the placement of supplemental information should not impede identification of GHS information.

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200		GHS
Appendix B Hazard determination (mandatory)	1.3.2.4	Available data, test methods, and test data quality
The quality of a hazard communication program is largely dependent upon the adequacy and accuracy of the hazard determination. The hazard determination requirement of this standard is performance oriented. Chemical manufacturers, importers, and employers evaluating chemicals are not required to follow any specific methods for determining hazards, but they must be able to demonstrate that they have adequately ascertained the hazards of the chemicals produced or imported in accordance with the criteria set forth in this Appendix.	1.3.2.4.1	The GHS itself does not include requirements for testing substances or mixtures. Therefore, there is no requirement under the GHS to generate test data for any hazard class. It is recognized that some parts of regulatory systems do require data to be generated (e.g., pesticides), but these requirements are not related specifically to the GHS. The criteria established for classifying a mixture will allow the use of available data for the mixture itself and/or similar mixtures and/or data for ingredients of the mixture.
… For purposes of this standard, the following criteria shall be used in making hazard determinations that meet the requirements of this standard.		
1. "Carcinogenicity." As described in paragraph (d)(4) of this section and Appendix A of this section, a determination by the National Toxicology Program, the International Agency for Research on Cancer, or OSHA that a chemical is a carcinogen or potential carcinogen will be considered conclusive evidence for purposes of this section. In addition, however, all available scientific data on carcinogenicity must be evaluated in accordance with the provisions of this Appendix and the requirements of the rule.		

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Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200		GHS
…	1.3.2.4.2	The classification of a chemical substance or mixture depends both on the criteria and on the reliability of the test methods underpinning the criteria. In some cases, the classification is determined by a pass or fail of a specific test (e.g., the ready biodegradation test for substances or ingredients of mixtures), while in other cases, interpretations are made from dose/response curves and observations during testing. In all cases, the test conditions need to be standardized so that the results are reproducible with a given chemical substance and the standardized test yields "valid" data for defining the hazard class of concern. In this context, validation is the process by which the reliability and the relevance of a procedure are established for a particular purpose.
4. "Adequacy and reporting of data." The results of any studies that are designed and conducted according to established scientific principles and that report statistically significant conclusions regarding the health effects of a chemical shall be a sufficient basis for a hazard determination and reported on any material safety data sheet. In vitro studies alone generally do not form the basis for a definitive finding of hazard under the HCS since they have a positive or negative result rather than a statistically significant finding.		Tests that determine hazardous properties, which are conducted according to internationally recognized scientific principles, can be used for purposes of a hazard determination for health and environmental hazards. The GHS criteria for determining health and environmental hazards are test method neutral, allowing different approaches as long as they are scientifically sound and validated according to international procedures and criteria already referred to in

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Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200		GHS
		existing systems for the hazard of concern and produce mutually acceptable data. Test methods for determining physical hazards are generally more clear-cut and are specified in the GHS.
The chemical manufacturer, importer, or employer may also report the results of other scientifically valid studies that tend to refute the findings of hazard.		Both positive and negative results are assembled together in the weight of evidence determination. However, a single positive study performed according to good scientific principles and with statistically and biologically significant positive results may justify classification.
		For classification purposes, reliable epidemiological data and experience on the effects of chemicals on humans (e.g., occupational data, data from accident databases) should be taken into account for the evaluation of human health hazards of a chemical. Testing on humans solely for hazard identification purposes is generally not acceptable.
	1.3.2.4.3	Tests that determine hazardous properties, which are conducted according to internationally recognized scientific principles, can be used for purposes of a hazard determination for health and environmental hazards. The GHS criteria for determining health and environmental hazards are test method neutral, allowing different approaches as long as they

(*Continued*)

Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
	are scientifically sound and validated according to international procedures and criteria already referred to in existing systems for the hazard of concern and produce mutually acceptable data. Test methods for determining physical hazards are generally more clear-cut and are specified in the GHS.
	1.3.2.4.4 Both positive and negative results are assembled together in the weight of evidence determination. However, a single positive study performed according to good scientific principles and with statistically and biologically significant positive results may justify classification.
"Human data." Where available, epidemiological studies and case reports of adverse health effects shall be considered in the evaluation.	1.3.2.4.5 *Evidence from humans* For classification purposes, reliable epidemiological data and experience on the effects of chemicals on humans (e.g., occupational data, data from accident databases) should be taken into account for the evaluation of human health hazards of a chemical. Testing on humans solely for hazard identification purposes is generally not acceptable.

(*Continued*)

Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
Not addressed in HCS.	1.3.2.4.6 *Animal welfare* The welfare of experimental animals is a concern. This ethical concern includes not only the alleviation of stress and suffering but also, in some countries, the use and consumption of test animals. Where possible and appropriate, tests and experiments that do not require the use of live animals are preferred to those using sentient live experimental animals. To that end, for certain hazards (skin and eye irritation/corrosion or serious damage), testing schemes starting with nonanimal observations/measurements are included as part of the classification system. For other hazards, such as acute toxicity, alternative animal tests, using fewer animals or causing less suffering, are internationally accepted and should be preferred to the conventional LD_{50} test.
"Animal data." Human evidence of health effects in exposed populations is generally not available for the majority of chemicals produced or used in the workplace. Therefore, the available results of toxicological testing in animal populations shall be used to predict the health effects that may be experienced by exposed workers. In particular, the definitions of certain acute hazards refer to specific animal testing results (see Appendix A).	

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Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200	**GHS**
Hazard evaluation is a process that relies heavily on the professional judgment of the evaluator, particularly in the area of chronic hazards. The performance orientation of the hazard determination does not diminish the duty of the chemical manufacturer, importer, or employer to conduct a thorough evaluation, examining all relevant data and producing a scientifically defensible evaluation.	1.3.2.4.7 *Expert judgment* The approach to classifying mixtures includes the application of expert judgment in a number of areas in order to ensure existing information can be used for as many mixtures as possible to provide protection for human health and the environment. Expert judgment may also be required in interpreting data for hazard classification of substances, especially where weight of evidence determinations are needed.
Hazard evaluation is a process that relies heavily on the professional judgment of the evaluator, particularly in the area of chronic hazards. The performance orientation of the hazard determination does not diminish the duty of the chemical manufacturer, importer, or employer to conduct a thorough evaluation, examining all relevant data and producing a scientifically defensible evaluation.	1.3.2.4.8 *Previously classified chemicals* One of the general principles established by the IOMC-CG-HCCS states that test data already generated for the classification of chemicals under the existing systems should be accepted when classifying these chemicals under the harmonized system, thereby avoiding duplicative testing and the unnecessary use of test animals. This policy has important implications in those cases where the criteria in the GHS are different from those in an existing system. In some cases, it may be difficult to determine the quality of existing data from older studies. In such cases, expert judgment will be needed.
CPL2-2.38D Hazard Determination	1.3.2.4.9 *Substances/mixtures posing special problems*

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Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200	GHS
Decomposition products that are produced during the normal use of the product or in foreseeable emergencies (e.g., plastics that are injection-molded, diesel fuel emissions) are covered. An employer may rely upon the hazard determination performed by the chemical manufacturer. Normally, the chemical manufacturer possesses knowledge of hazardous intermediates, by-products, and decomposition products that can be emitted by their product.	The effect of a substance or mixture on biological and environmental systems is influenced, among other factors, by the physicochemical properties of the substance or mixture and/or ingredients of the mixture and the way in which ingredient substances are biologically available. Some groups of substances may present special problems in this respect, for example, some polymers and metals. A substance or mixture need not be classified when it can be shown by conclusive experimental data from internationally acceptable test methods that the substance or mixture is not
Any substance that is inextricably bound in a product is not covered under the HCS. For example, a hazard determination for a product containing crystalline silica may reveal that it is bound in a rubber elastomer and under normal conditions of use or during foreseeable emergencies cannot become airborne and, therefore, cannot present an inhalation hazard. In such a situation, the crystalline silica need not be indicated as a hazardous ingredient since it cannot result in employee exposure.	biologically available. Similarly, bioavailability data on ingredients of a mixture should be used where appropriate in conjunction with the harmonized classification criteria when classifying mixtures.

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Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200		GHS
"Adequacy and reporting of data." The results of any studies that are designed and conducted according to established scientific principles and that report statistically significant conclusions regarding the health effects of a chemical shall be a sufficient basis for a hazard determination and reported on any material safety data sheet. In vitro studies alone generally do not form the basis for a definitive finding of hazard under the HCS since they have a positive or negative result rather than a statistically significant finding.	1.3.2.4.10	*Weight of evidence*
The chemical manufacturer, importer, or employer may also report the results of other scientifically valid studies that tend to refute the findings of hazard.	1.3.2.4.10.1	For some hazard classes, classification results directly when the data satisfy the criteria. For others, classification of a substance or a mixture is made on the basis of the total weight of evidence. This means that all available information bearing on the determination of toxicity is considered together, including the results of valid in vitro tests, relevant animal data, and human experience such as epidemiological and clinical studies and well-documented case reports and observations.

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Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200		GHS
	1.3.2.4.10.2	The quality and consistency of the data are important. Evaluation of substances or mixtures related to the material being classified should be included, as should site of action and mechanism or mode of action study results. Both positive and negative results are assembled together in a single weight of evidence determination.
	1.3.2.4.10.3	Positive effects that are consistent with the criteria for classification in each chapter, whether seen in humans or animals, will normally justify classification. Where evidence is available from both sources and there is a conflict between the findings, the quality and reliability of the evidence from both sources must be assessed in order to resolve the question of classification. Generally, data of good quality and reliability in humans will have precedence over other data. However, even well-designed and conducted epidemiological studies may lack sufficient numbers of subjects to detect relatively rare but still significant effects, or to assess potentially confounding factors. Positive results from well-conducted animal studies are not necessarily negated by the lack of positive human experience but require an assessment of the robustness and

(*Continued*)

Hazard Determinations/Classification Provisions

Comparison

The GHS and HCS hazard determination/classification are self-classification processes. As classification is more involved in the GHS, additional guidance could be useful. The GHS includes weight of evidence in the hazard determination. The HCS has a one positive study threshold. The GHS provides for the one positive study issue within the individual endpoints. In vitro studies are treated differently. Substances not bioavailable or inextricably bound are addressed. Professional/expert judgment is included. Human experience is taken into account. In the HCS, negative findings and data that refute findings of hazard are allowed. The HCS does not address animal welfare.

The GHS addresses the import concept of previously classified substances. Existing data should be accepted when classifying substances under the GHS.

OSHA HCS 29 CFR 1910.1200		GHS
		quality of both the human and animal data relative to the expected frequency of occurrence of effects and the impact of potentially confounding factors.
	1.3.2.4.10.4	Route of exposure, mechanistic information, and metabolism studies are pertinent to determining the relevance of an effect in humans. When such information raises doubt about relevance in humans, a lower classification may be warranted. When it is clear that the mechanism or mode of action is not relevant to humans, the substance or mixture should not be classified.

Comparison of Health Hazards

General Comments

The GHS has several health hazard endpoints (e.g., mutagenicity and target organ systemic toxicity) that do not exactly correspond to the HCS hazards. In general, the major difference between the HCS and the GHS is untested mixtures. OSHA has a single 1% cutoff value for all health hazards, except carcinogens at 0.1%. These cutoff values require labels, MSDSs, and disclosure of hazardous components. In the GHS, cutoff values for mixtures vary by endpoint. The GHS cutoff values for labeling, MSDSs, and disclosure can be different. The GHS acute toxicity and irritant hazard determinations for mixtures have more steps.

For substances previously classified under the HCS, existing data should be accepted when these substances are classified under the GHS.

Acute Toxicity

Comparison

Five GHS categories have been included in the GHS Acute Toxicity scheme from which the appropriate elements relevant to means of transport, consumer, worker, and environment protection can be selected. The HCS has two Acute Toxicity hazard categories whose cutoff values do not exactly correspond to the GHS cutoffs. The untested mixture hazard determination is different in the HCS and GHS. The GHS Acute Toxicity hazard determination for mixtures is involved. Acute Toxicity is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
Criteria	**Criteria**
Substances and mixtures are assigned to one of two acute toxicity hazards on the basis of LD_{50}/LC_{50}:	Substances of this hazard class are assigned to one of five toxicity categories on the basis of LD_{50} (oral, dermal) or LC_{50} (inhalation):
	Category 1
	LD_{50} < 5 mg/kg bodyweight (oral)
	LD_{50} < 50 mg/kg bodyweight (skin/dermal)
	LC_{50} < 100 ppm (gas)
	LC_{50} < 0.5 (mg/L) (vapor)
	LC_{50} < 0.05 (mg/L) (dust, mist)
	Category 2
	LD_{50} > 5 and <50 mg/kg bodyweight (oral)
	LD_{50} > 50 and <200 mg/kg bodyweight (skin/dermal)
	LD_{50} > 100 and <500 ppm (gas)
	LD_{50} > 0.5 and <2.0 (mg/L) (vapor)
	LC_{50} > 0.05 and <0.5 (mg/L) (dust, mist)
	Category 3
	LD_{50} > 50 and <300 mg/kg bodyweight (oral)
"*Highly toxic.*" A chemical falling within any of the following categories:	LD_{50} > 200 and <1000 mg/kg bodyweight (skin/dermal)
(a) A chemical that has a median lethal dose (LD_{50}) of 50 mg or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 g each.	LC_{50} > 500 and <2500 ppm (gas)

(*Continued*)

Acute Toxicity

Comparison

Five GHS categories have been included in the GHS Acute Toxicity scheme from which the appropriate elements relevant to means of transport, consumer, worker, and environment protection can be selected. The HCS has two Acute Toxicity hazard categories whose cutoff values do not exactly correspond to the GHS cutoffs. The untested mixture hazard determination is different in the HCS and GHS. The GHS Acute Toxicity hazard determination for mixtures is involved. Acute Toxicity is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
(b) A chemical that has a median lethal dose (LD_{50}) of 200 mg or less per kilogram of body weight when administered by continuous contact for 24 h (or less if death occurs within 24 h) with the bare skin of albino rabbits weighing between 2 and 3 kg each.	LC_{50} > 2.0 and <10.0 (mg/L) (vapor)
(c) A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 mg/L or less of mist, fume, or dust, when administered by continuous inhalation for 1 h (or less if death occurs within 1 h) to albino rats weighing between 200 and 300 g each.	
"*Toxic.*" A chemical falling within any of the following categories:	LC_{50} > 0.5 and <1.0 (mg/L) (dust, mist) *Category 4* LD_{50} between 300 and less than 2000 mg/kg bodyweight (oral) LD_{50} between 1000 and less than 2000 mg/kg bodyweight (skin/dermal) LC_{50} between 2500 and less than 5000 ppm (gas) LC_{50} between 10.0 and less than 20.0 (mg/L) (vapor) LC_{50} between 1.0 and less than 5.0 (mg/L) (dust, mist) *Category 5* LD_{50} between 2000 and 5000 (oral or skin/dermal) For gases, vapors, dusts, and mists, LC_{50} in the equivalent range of the oral and dermal LD_{50} (i.e., between 2000 and 5000 mg/kg body weight). See also the additional criteria: • Indication of significant effect in humans

(*Continued*)

Acute Toxicity

Comparison

Five GHS categories have been included in the GHS Acute Toxicity scheme from which the appropriate elements relevant to means of transport, consumer, worker, and environment protection can be selected. The HCS has two Acute Toxicity hazard categories whose cutoff values do not exactly correspond to the GHS cutoffs. The untested mixture hazard determination is different in the HCS and GHS. The GHS Acute Toxicity hazard determination for mixtures is involved. Acute Toxicity is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
	• Any mortality in Category 4 • Significant clinical signs in Category 4 • Indication from other studies. • For mixtures: • Conversion values for range tests or hazard categories are in Table 3.1.2. "Relevant components" are those present at >1% (w/w for solids, liquids, dusts, mists, and vapors and v/v for gases), unless there is a reason to suspect that an ingredient present at <1% is still relevant. • Apply bridging principles • If bridging principles do not apply • If data available for all components or data is available to estimate and unknown components <10% apply
(a) A chemical that has a median lethal dose (LD_{50}) of more than 50 mg/kg but not more than 500 mg/kg of body weight when administered orally to albino rats weighing between 200 and 300 g each. (b) A chemical that has a median lethal dose (LD_{50}) of more than 200 mg/kg but not more than 1000 mg/kg of body weight when administered by continuous contact for 24 h (or less if death occurs within 24 h) with the bare skin of albino rabbits weighing between 2 and 3 kg each. (c) A chemical that has a median lethal concentration (LC_{50}) in air of more than 200 parts per million but not more than 2000 parts per million by volume of gas or vapor, or more than 2 mg/L but not more than 20 mg/L of mist, fume, or dust, when administered by continuous inhalation for 1 h (or less if death occurs within 1 h) to albino rats weighing between 200 and 300 g each.	

(*Continued*)

Acute Toxicity

Comparison

Five GHS categories have been included in the GHS Acute Toxicity scheme from which the appropriate elements relevant to means of transport, consumer, worker, and environment protection can be selected. The HCS has two Acute Toxicity hazard categories whose cutoff values do not exactly correspond to the GHS cutoffs. The untested mixture hazard determination is different in the HCS and GHS. The GHS Acute Toxicity hazard determination for mixtures is involved. Acute Toxicity is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
For mixtures: Untested mixtures are assumed to present the same health hazards as components present at >1% (by weight or volume).	where Ci = concentration of ingredient i n ingredients and i is running from 1 to n ATE_i = acute toxicity estimate of ingredient i. • When unknown components >10%, apply $$\frac{100}{ATE_{mix}} = \sum_n \frac{C_i}{ATE_i}$$ where C_i = concentration of ingredient i n ingredients and i is running from 1 to n ATE_i = acute toxicity estimate of ingredient i. • When unknown components >10%, apply $$\frac{100 - \left(\sum C_{unknown} \text{if} > 10\%\right)}{ATE_{mix}} = \sum_n \frac{C_i}{ATE_i}$$

Skin Corrosion

Comparison

A single harmonized GHS Corrosion category is provided. For authorities wanting more than one designation for corrosivity, up to three subcategories are provided within the Corrosive category. Only some authorities will use the subcategories in Corrosive category 1. The HCS has one Corrosion hazard category. The untested mixture hazard determination is different in the HCS and GHS.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria *"Corrosive."* A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. For example, a chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described by the US Department of Transportation in Appendix A to 49 CFR part 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of 4 h. This term shall not refer to action on inanimate surfaces.	**Definition** Skin corrosion means the production of irreversible damage to the skin following the application of a test substance for up to 4 h.
For mixtures: Untested mixtures are assumed to present the same health hazards as components present at >1% (by weight or volume).	**Criteria** Substances and mixtures in this hazard class are assigned to a single harmonized corrosion category. Category 1 1. *For substances and tested mixtures:* • Human experience showing irreversible damage to the skin • Structure/activity or structure/property relationship to a substance or mixture already classified as corrosive • pH extremes of <2 and >11.5 including acid/alkali reserve capacity • Positive results in a valid and accepted in vitro skin corrosion test • Animal experience or test data indicate that the substance/mixture causes irreversible damage to the skin following exposure of up to 4 h (see Table 3.2.1)

(*Continued*)

Skin Corrosion

Comparison

A single harmonized GHS Corrosion category is provided. For authorities wanting more than one designation for corrosivity, up to three subcategories are provided within the Corrosive category. Only some authorities will use the subcategories in Corrosive category 1. The HCS has one Corrosion hazard category. The untested mixture hazard determination is different in the HCS and GHS.

OSHA HCS 29 CFR 1910.1200	GHS
	2. *If data for a mixture are not available,* use bridging principles in 3.2.3.2. 3. *If bridging principles do not apply* (a) For mixtures where substances can be added: Classify as corrosive if the sum of the concentrations of corrosive substances in the mixture is >5% (for substances with additivity) (b) For mixtures where substances cannot be added: ≥1% corrosive substance. See 3.2.3.3.4. For those authorities wanting more than one designation for corrosivity, up to three subcategories are provided within the corrosive category: Subcategory 1A: ≤3 min exposure and <1 h observation Subcategory 1B: >3 min <1 h exposure and <14 days observation Subcategory 1C: >1 h and ≤4 h exposure and <14 days observation

Skin Irritation

Comparison

A single harmonized GHS skin irritant category is provided. An additional mild irritant category is available for authorities that want to have more than one skin irritant category. The HCS has one skin irritation hazard category. The untested mixture hazard determination is quite different in the HCS and GHS. The GHS irritant hazard determination for mixtures is involved. Irritation data is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria	**Definition**
"Irritant." A chemical that is not corrosive but that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 CFR 1500.41 for 4 h exposure or by other appropriate techniques, it results in an empirical score of five or more. For mixtures: Untested mixtures are assumed to present the same health hazards as components present at ≥1% (by weight or volume).	Skin irritation means the production of reversible damage to the skin following the application of a test substance for up to 4 h. **Criteria** Substances and mixtures in this hazard class are assigned to a single irritant category. Category 2 • 1. *For substances and tested mixtures* • Human experience or data show reversible damage to the skin following exposure of up to 4 h • Structure/activity or structure/property relationship to a substance or mixture already classified as an irritant • Positive results in a valid and accepted in vitro skin irritation test • Animal experience or test data indicate that the substance/mixture causes reversible damage to the skin following exposure of up to 4 h, with a mean value of >2.3 < 4.0 for erythema/ eschar or for edema, or inflammation that persists to the end of the observation period, in two of three tested animals (Table 3.2.2). 2. *If data for a mixture are not available,* use bridging principles in 3.2.3.2. 3. *If bridging principles do not apply,* classify as an irritant if (a) For mixtures where substances can be added, the sum of concentrations of corrosive substances in the mixture is >1% but <5%; the sum of the concentrations of irritant substances (Cat 2) is >10%; or the sum of (10 × the concentrations of corrosive ingredients) + (the concentrations of irritant ingredients (Cat 2)) is >10% (b) For mixtures where substances cannot be added: ≥3% an irritant substance (Cat 2) (see 3.2.3.3.4) • For those authorities wanting more than one designation for skin irritation, an additional mild irritant category is provided:

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Skin Irritation

Comparison

A single harmonized GHS skin irritant category is provided. An additional mild irritant category is available for authorities that want to have more than one skin irritant category. The HCS has one skin irritation hazard category. The untested mixture hazard determination is quite different in the HCS and GHS. The GHS irritant hazard determination for mixtures is involved. Irritation data is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
	Category 3 • 1. *For substances and tested mixtures* • Animal experience or test data indicate that the substance/mixture causes reversible damage to the skin following exposure of up to 4 h, with a mean value of >1.5 <2.3 for erythema/ eschar in two of three tested animals (see Table 3.2.2) 2. *If data for a mixture are not available,* use bridging principles in 3.2.3.2. 3. *If bridging principles do not apply,* classify as a mild irritant if • For mixtures where substances can be added, the sum of the concentrations of irritant substances (Cat 2) in the mixture is >1% but <10% • The sum of the concentrations of mild irritant substances (Cat 3) is >10% • The sum of (10× the concentrations of corrosive substances) + (the concentrations of irritant substances (Cat 2)) is >1% but <10% • The sum of (10× the concentrations of corrosive substances) + (the concentrations of irritant substances (Cat 2)) + (the concentrations of mild irritant substances (Cat 3)) is >10%

Serious Eye Damage

Comparison

A single GHS eye irritant category (Cat 2A) is provided. An additional mild eye irritant category (Cat 2B) is available for authorities that want to have more than one eye irritant category. The HCS has one eye irritation hazard category. In the GHS, skin irritants can be considered to be eye irritants. The untested mixture hazard determination is different in the HCS and GHS. The GHS eye irritant hazard determination for mixtures is involved. Irritation data is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria *"Irritant."* A chemical that is not corrosive but that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is an eye irritant if so determined under the procedure listed in 16 CFR 1500.42 or other appropriate techniques. For mixtures: Untested mixtures are assumed to present the same health hazards as components present at >1% (by weight or volume).	**Definition** Eye irritation means the production of changes in the eye following the application of test substance to the anterior surface of the eye, which are fully reversible within 21 days of application. **Criteria** Substances of this hazard class are assigned to a single harmonized hazard category, or for authorities wanting more than one designation for eye irritation, one of two subcategories depending on whether effects are reversible in 21 or 7 days. For those authorities wanting more than one designation for eye irritation, two subcategories are provided within the eye irritation category: Category 2A—Irritant 1. *Substances and tested mixtures* Classification as (severe) skin irritant Human experience or data showing production of changes in the eye that are fully reversible within 21 days Structure/activity or structure/property relationship to a substance or mixture already classified as an eye irritant Positive results in a valid and accepted in vitro eye irritation test Animal experience or test data indicate that the substance/mixture produces a positive response in at least two of three tested animals of corneal opacity >1, iritis >1, or conjunctival edema (chemosis) >2 (Table 3.3.2).

(*Continued*)

Serious Eye Damage

Comparison

A single GHS eye irritant category (Cat 2A) is provided. An additional mild eye irritant category (Cat 2B) is available for authorities that want to have more than one eye irritant category. The HCS has one eye irritation hazard category. In the GHS, skin irritants can be considered to be eye irritants. The untested mixture hazard determination is different in the HCS and GHS. The GHS eye irritant hazard determination for mixtures is involved. Irritation data is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
	2. *If data for a mixture are not available,* use bridging principles in 3.3.3.2. 3. *If bridging does not apply*, classify as an irritant (2A) if (a) For mixtures where substances can be added: the sum of the concentrations of skin and/or eye Category 1 substances in the mixture is >1% but <3%; the sum of the concentrations of eye irritant substances (Cat 2/2A) is >10%; or the sum of (10× the concentrations of skin and/or eye Category 1 substances) + (the concentrations of eye irritants (2A/2B)) is >10% skin Cat 1 + eye Cat 1 is >1% but <3%; or (10× eye Category 1) + eye Cat 2A/2B is >10% (b) For mixtures where substances cannot be added: the sum of the concentrations of eye irritant ingredients (Cat 2) is >3% (see 3.3.3.3.4) Category 2B—Mild Irritant An eye irritant is considered mildly irritating to eyes (Category 2B) when the effects listed above (Cat 2A) are fully reversible within 7 days of observation.

Eye Irritation

Comparison

A single GHS eye irritant category (Cat 2A) is provided. An additional mild eye irritant category (Cat 2B) is available for authorities that want to have more than one eye irritant category. The HCS has one eye irritation hazard category. In the GHS, skin irritants can be considered to be eye irritants. The untested mixture hazard determination is different in the HCS and GHS. The GHS eye irritant hazard determination for mixtures is involved. Irritation data is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria *"Irritant."* A chemical that is not corrosive but that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is an eye irritant if so determined under the procedure listed in 16 CFR 1500.42 or other appropriate techniques.	**Definition** Eye irritation means the production of changes in the eye following the application of test substance to the anterior surface of the eye, which are fully reversible within 21 days of application.
For mixtures: Untested mixtures are assumed to present the same health hazards as components present at >1% (by weight or volume).	**Criteria** Substances of this hazard class are assigned to a single harmonized hazard category, or for authorities wanting more than one designation for eye irritation, one of two subcategories depending on whether effects are reversible in 21 or 7 days. For those authorities wanting more than one designation for eye irritation, two subcategories are provided within the eye irritation category: Category 2A—Irritant 1. *Substances and tested mixtures* • Classification as (severe) skin irritant • Human experience or data showing production of changes in the eye that are fully reversible within 21 days • Structure/activity or structure/property relationship to a substance or mixture already classified as an eye irritant • Positive results in a valid and accepted in vitro eye irritation test • Animal experience or test data indicate that the substance/mixture produces a positive response in at least two of three tested animals of corneal opacity >1, iritis >1, or conjunctival edema (chemosis) >2 (Table 3.3.2).

(*Continued*)

Eye Irritation

Comparison

A single GHS eye irritant category (Cat 2A) is provided. An additional mild eye irritant category (Cat 2B) is available for authorities that want to have more than one eye irritant category. The HCS has one eye irritation hazard category. In the GHS, skin irritants can be considered to be eye irritants. The untested mixture hazard determination is different in the HCS and GHS. The GHS eye irritant hazard determination for mixtures is involved. Irritation data is a common data set.

OSHA HCS 29 CFR 1910.1200	GHS
	2. *If data for a mixture are not available,* use bridging principles in 3.3.3.2. 3. *If bridging does not apply*, classify as an irritant (2A) if (a) For mixtures where substances can be added: the sum of the concentrations of skin and/or eye Category 1 substances in the mixture is >1% but <3%; the sum of the concentrations of eye irritant substances (Cat 2/2A) is >10%; or the sum of (10× the concentrations of skin and/or eye Category 1 substances) + (the concentrations of eye irritants(2A/2B)) is >10% skin Cat 1 + eye Cat 1 is >1% but <3%; or (10× eye Category 1) + eye Cat 2A/2B is >10% (b) For mixtures where substances cannot be added: the sum of the concentrations of eye irritant ingredients (Cat 2) is >3% (see 3.3.3.3.4) Category 2B—Mild Irritant An eye irritant is considered mildly irritating to eyes (Category 2B) when the effects listed above (Cat 2A) are fully reversible within 7 days of observation.

Respiratory Sensitizer

Comparison

The untested mixture hazard determination may be different in the HCS and GHS. OSHA will need to determine how to implement the mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria "*Sensitizer.*" A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical. For mixtures: Untested mixtures are assumed to present the same health hazards as components present at >1% (by weight or volume).	**Definition** Respiratory sensitizer means a substance that induces hypersensitivity of the airways following inhalation of the substance. **Criteria** Substances and mixtures in this hazard class are assigned to one hazard category. 1. *For substances and tested mixture* If there is human evidence that the individual substance induces specific respiratory hypersensitivity Where there are positive results from an appropriate animal test 2. *If the mixture meets the criteria* set forth in the "Bridging Principles" through one of the following: (a) Dilution (b) Batching (c) Substantially similar mixture 3. *If bridging principles do not apply*: Mixtures containing >0.1% or >1.0% (solid/liquid) (0.2% gas) of such a substance. See Notes, Table 3.4.1, Chapter 3.4.

Skin Sensitizer

Comparison

The untested mixture hazard determination may be different in the HCS and GHS. OSHA will need to determine how to implement the mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria *"Sensitizer."* A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical. For mixtures: Untested mixtures are assumed to present the same health hazards as components present at ≥1% (by weight or volume).	**Definition** Skin sensitizer means a substance that will induce an allergic response following skin contact. The definition for "skin sensitizer" is equivalent to "contact sensitizer." **Criteria** Substances and mixtures in this hazard class are assigned to one hazard category. 1. *For substances and tested mixture* • If there is evidence in humans that the individual substance can induce sensitization by skin contact in a substantial number of persons • Where there are positive results from an appropriate animal test 2. *If the mixture meets the criteria* set forth in the "Bridging Principles" through one of the following: (a) Dilution (b) Batching (c) Substantially similar mixture 3. *If bridging principles do not apply*: Mixtures containing >0.1% or >1.0% of such a substance. See Notes, Table 3.4.1, Chapter 3.4.

Mutagenicity

Comparison

Since they have a positive or negative result rather than a statistically significant finding, the HCS does not generally consider in vitro studies alone to form the basis for a definitive finding of hazard. The HCS addresses chromosomal damage under reproductive toxins. The HCS allows test data on mixtures to be used for all hazard classes. The untested mixture hazard determination may be different in the HCS and GHS.

The GHS provides for two hazard categories to accommodate the weight of evidence. Since this hazard class is not an exact match with the HCS, consideration could be given as to how to implement this hazard class/category.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria	**Definition**
Chemicals that affect reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis)	Mutagen means an agent giving rise to an increased occurrence of mutations in populations of cells and/or organisms.
In vitro studies alone generally do not form the basis for a definitive finding of hazard under the HCS since they have a positive or negative result rather than a statistically significant finding.	**Criteria** Substances and mixtures of this hazard class are assigned to one of two hazard categories. Category 1 has two subcategories. Category 1 Subcategory 1A: Known to induce heritable mutations in the germ cells of humans • Positive evidence from human epidemiological studies
For mixtures: Untested mixtures are assumed to present the same health hazards as components present at ≥1% (by weight or volume).	Subcategory 1B: Regarded as if it induces heritable mutations in the germ cells of humans • Positive in vivo heritable germ cell mutagenicity tests in mammals • Positive in vivo somatic cell mutagenicity tests in mammals and evidence for potential germ cell mutations • Tests showing mutagenic effects in human germ cells without demonstration of transmission to progeny See criteria in 3.5.2. Mixtures containing >0.1% of such a substance. Category 2 Causes concern for man owing to the possibility that it may induce heritable mutations in the germ cells of humans • Evidence in mammals and/or in vitro • In vivo somatic cell mutagenicity tests in mammals • In vivo somatic cell genotoxicity with in vitro mutagenicity assays See criteria in 3.5.2. Mixtures containing >1.0% of such a substance.

Carcinogenicity

Comparison

The HCS allows test data on mixtures to be used for all hazard classes. The GHS allows the HCS provision for inclusion on safety data sheets of positive results in any carcinogenicity study performed according to good scientific principles with statistically significant results. The HCS will need to determine the implementation of the GHS mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria *"Carcinogen."* A chemical is considered to be a carcinogen if (a) It has been evaluated by the International Agency for Research on Cancer (IARC) and found to be a carcinogen or potential carcinogen (b) It is listed as a carcinogen or potential carcinogen in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition) (c) It is regulated by OSHA as a carcinogen OSHA has issued guidance on how IARC classifications apply to the HCS. Similar guidance for the GHS categories would be useful. For mixtures: Untested mixtures are assumed to present a carcinogenic hazard if components present at >0.1% are considered to be a carcinogen.	**Definition** Carcinogen means a chemical substance or a mixture of chemical substances that induce cancer or increase its incidence. **Criteria** Substances and mixtures of this hazard class are assigned to one of two hazard categories. Category 1 has two subcategories. Category 1: Known or presumed human carcinogen Category 1A: Known human carcinogen • Based on human evidence Category 1B: Presumed human carcinogen • Strength of evidence with additional considerations • Evidence of animal carcinogenicity (presumed human carcinogen) • On a case-by-case basis, limited evidence of carcinogenicity in humans together with limited evidence of carcinogenicity in animals. Including mixtures containing ≥0.1% of such a substance. Category 2: Suspected human carcinogen • Evidence from human and/or animal studies • Strength of evidence together with additional considerations Including mixtures containing more than ≥0.1% or ≥1.0% of such a substance. (See Notes 1 and 2 of Table 3.6.1 of Chapter 3.6.)

Reproductive Toxicity

Comparison

The HCS allows test data on mixtures to be used for all hazard classes. The untested mixture hazard determination is different in the HCS and GHS. The HCS will need to determine the implementation of the GHS mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria	**Criteria**
"Reproductive toxins." Chemicals that affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis)	Effects on reproductive ability or capacity and on development are considered separate issues. Substances and mixtures of this hazard class are assigned to one of two hazard categories. Category 1 has two subcategories.
Signs and symptoms: Birth defects; sterility	Category 1: Known or presumed human reproductive/developmental toxicants
Chemicals: Lead; DBCP	Category 1A: Known human reproductive or developmental toxicants
For mixtures:	
Untested mixtures are assumed to present the same health hazards as components present at ≥1% (by weight or volume).	• Human evidence Category 1B: Presumed human reproductive/developmental toxicants • Evidence from experimental animals See criteria in 3.7.2.2.1 to 3.7.2.6.0 of Chapter 3.7. Mixtures containing ≥0.1% or ≥0.3% of such a substance. See Notes 1 and 2 of Table 3.7.1, Chapter 3.7. Category 2: Suspected human reproductive/developmental toxicants • Evidence from humans or experimental animals, possibly supplemented with other information. See criteria in 3.7.2.2.1 to 3.7.2.6.0 of Chapter 3.7. Mixtures containing ≥0.1% or ≥3.0% of such a substance. See Notes 3 and 4 of Table 3.7.1, Chapter 3.7.

Effects on or via Lactation

Comparison
This special category is not specifically addressed in the HCS.

OSHA HCS 29 CFR 1910.1200	GHS
Definition	**Criteria**
Criteria	Effects on or via lactation are assigned to a separate single category. Special Category Substances that cause concern for the health of breastfed children • Absorption, metabolism, distribution, and excretion studies indicating the likelihood that the substance is present in potentially toxic levels in breast milk • Evidence from one or two generation studies of adverse effects in the offspring due to transfer in the milk or adverse effects on the quality of the milk • Human evidence indicating a hazard to babies during the lactation period See criteria in 3.7.2.2.1 to 3.7.2.6.0 and 3.7.3.4 of Chapter 3.7.

Target Organ Systemic Toxicity after Single Exposure

Comparison

The HCS does not distinguish between single and repeat exposure for target organ effects. The GHS provides guidance on dose/concentration value ranges. The untested mixture hazard determination is different in the HCS and GHS. The HCS will need to determine the implementation of the GHS mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria **"Target organ effects."** The following is a target organ categorization of effects that may occur, including examples of signs and symptoms and chemicals that have been found to cause such effects. These examples are presented to illustrate the range and diversity of effects and hazards found in the workplace, and the broad scope employers must consider in this area, but are not intended to be all-inclusive. a. Hepatotoxins: Chemicals that produce liver damage Signs and symptoms: Jaundice; liver enlargement Chemicals: Carbon tetrachloride; nitrosamines b. Nephrotoxins: Chemicals that produce kidney damage. Signs and symptoms: Edema; proteinuria chemicals: Halogenated hydrocarbons; uranium c. Neurotoxins: Chemicals that produce their primary toxic effects on the nervous system Signs and symptoms: Narcosis; behavioral changes; decrease in motor functions Chemicals: Mercury; carbon disulfide d. Agents that act on the blood or hematopoietic system: They decrease hemoglobin function and deprive the body tissues of oxygen Signs and symptoms: Cyanosis; loss of consciousness Chemicals: Carbon monoxide; cyanides	**Criteria** All significant health effects that can impair function, both reversible and irreversible, immediate and/or delayed, are included in the nonlethal target organ/systemic toxicity class. Substances and mixtures of this hazard class are assigned to one of two hazard categories based on evidence for substance or mixture (including bridging). Category 1: Significant toxicity in humans Adverse effect on specific organ/systems: • Human cases or epidemiological studies • Animal studies with severe effects at low dose • Guidance values in Table 3.8.1 as part of weight-of-evidence evaluation Mixture that lacks sufficient data but contains Category 1 ingredient at a concentration of >1% to ≥10% for some authorities and contains Category 1 ingredient at a concentration >10% for all authorities (see Notes of Table 3.8.2) Category 2: Harmful to humans Adverse effect on specific organ/systems: • Animal studies with significant toxicity at moderate dose, • considering weight of evidence and guidance values in Table 3.8.1 Mixture that lacks sufficient data, but contains Category 1 ingredient: >1% but <10% for some authorities and ≥10% for all authorities (see Notes of Table 3.8.2), and/or contains Category 2 ingredient: >1% but ≥10% for some authorities and >10% for all authorities (see Notes of Table 3.8.2)

(*Continued*)

Target Organ Systemic Toxicity after Single Exposure

Comparison

The HCS does not distinguish between single and repeat exposure for target organ effects. The GHS provides guidance on dose/concentration value ranges. The untested mixture hazard determination is different in the HCS and GHS. The HCS will need to determine the implementation of the GHS mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
e. Agents that damage the lungs: Chemicals that irritate or damage pulmonary tissue Signs and symptoms: Cough; tightness in chest; shortness of breath Chemicals: Silica; asbestos f. Reproductive toxins: Chemicals that affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis) Signs and symptoms: Birth defects; sterility Chemicals: Lead; DBCP g. Cutaneous hazards: Chemicals that affect the dermal layer of the body Signs and symptoms: Defatting of the skin; rashes; irritation Chemicals: Ketones; chlorinated compounds h. Eye hazards: Chemicals that affect the eye or visual capacity Signs and symptoms: Conjunctivitis; corneal damage Chemicals: Organic solvents; acids For mixtures: Untested mixtures are assumed to present the same health hazards as components present at ≥1% (by weight or volume).	

Target Organ Systemic Toxicity after Repeat Exposure

Comparison

The HCS does not distinguish between single and repeat exposure for target organ effects. The GHS provides guidance on dose/concentration value ranges. The untested mixture hazard determination may be different in the HCS and GHS. The HCS will need to determine the implementation of the GHS mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
Definition/Criteria **"Target organ effects."** The following is a target organ categorization of effects that may occur, including examples of signs and symptoms and chemicals that have been found to cause such effects. These examples are presented to illustrate the range and diversity of effects and hazards found in the workplace and the broad scope employers must consider in this area, but are not intended to be all-inclusive. a. Hepatotoxins: Chemicals that produce liver damage Signs and symptoms: Jaundice; liver enlargement Chemicals: Carbon tetrachloride; nitrosamines b. Nephrotoxins: Chemicals that produce kidney damage Signs and symptoms: Edema; proteinuria Chemicals: Halogenated hydrocarbons; uranium c. Neurotoxins: Chemicals that produce their primary toxic effects on the nervous system Signs and symptoms: Narcosis; behavioral changes; decrease in motor functions Chemicals: Mercury; carbon disulfide d. Agents that act on the blood or hematopoietic system: They decrease hemoglobin function and deprive the body tissues of oxygen Signs and symptoms: Cyanosis; loss of consciousness Chemicals: Carbon monoxide; cyanides e. Agents that damage the lungs: Chemicals that irritate or damage pulmonary tissue Signs and symptoms: Cough; tightness in chest; shortness of breath Chemicals: Silica; asbestos	**Criteria** All significant health effects that can impair function, both reversible and irreversible, immediate and/or delayed, are included in the nonlethal target organ/systemic toxicity class. Substances and mixtures of this hazard class are assigned to one of two hazard categories based on evidence for substance or mixture (including bridging). Category 1: Significant toxicity in humans Adverse effect on specific organ/systems: • Human cases or epidemiological studies • Animal studies with severe effects at low dose • Guidance values in Table 3.9.1, as part of weight-of-evidence evaluation Mixture that lacks sufficient data but contains Category 1 ingredient at a concentration of >1% to <10% for some authorities, and contains Category 1 ingredient at a concentration >10.0% for all authorities (see Notes of Table 3.9.3) Category 2: Harmful to humans Adverse effect on specific organ/systems: • Animal studies with significant toxicity at moderate dose, considering weight of evidence and guidance values in Table 3.9.1

(*Continued*)

Target Organ Systemic Toxicity after Repeat Exposure

Comparison

The HCS does not distinguish between single and repeat exposure for target organ effects. The GHS provides guidance on dose/concentration value ranges. The untested mixture hazard determination may be different in the HCS and GHS. The HCS will need to determine the implementation of the GHS mixture cutoff values.

OSHA HCS 29 CFR 1910.1200	GHS
f. Reproductive toxins: Chemicals that affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis) Signs and symptoms: Birth defects; sterility Chemicals: Lead; DBCP g. Cutaneous hazards: Chemicals that affect the dermal layer of the body Signs and symptoms: Defatting of the skin; rashes; irritation Chemicals: Ketones; chlorinated compounds h. Eye hazards: Chemicals that affect the eye or visual capacity Signs and symptoms: Conjunctivitis; corneal damage Chemicals: Organic solvents; acids For mixtures: Untested mixtures are assumed to present the same health hazards as components present at >1% (by weight or volume).	• Mixture that lacks sufficient data, but contains Category 1 ingredient: >1% but <10% for some authorities and >10% for all authorities (see Note 3 of Table 3.9.3), and/or contains Category 2 ingredient: >1% but <10% for some authorities and >10% for all authorities (see Notes of Table 3.9.3)

Comparison of Physical Hazards

Comparison of OSHA HCS and GHS Criteria

Explosives

Comparison

The HCS has only one hazard category for explosives and the GHS has six hazard categories. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria	
Test Method	**Test Method**	
HCS has no test method.	UN Manual of Tests and Criteria Part I Test Series 2 to 7 Recommended tests for explosives (including articles)	
	2(a)	UN Gap test
	2(b)	Koenen test
	2(c)	Time/pressure test
	3(a)(ii)	BAM Fallhammer
	3(b)(i)	BAM Friction apparatus
	3(c)	Thermal stability test at 75°C
	3(d)	Small-scale burning test
	4(a)	Thermal stability test for unpackaged articles and packaged articles
	4(b)(i)	Steel tube drop test for liquids
	4(b)(ii)	Twelve-meter drop test for unpackaged articles, packaged articles, and packaged substances
	5(a)	Cap sensitivity test
	5(b)(ii)	USA DDT test
	5(c)	External fire test for Division 1.5
	6(a)	Single package test
	6(b)	Stack test
	6(c)	External fire (bonfire) test
	7(a)	EIDS cap test
	7(b)	EIDS gap test
	7(c)(ii)	Friability test
	7(d)(i)	EIDS bullet impact test
	7(e)	EIDS external fire test
	7(f)	EIDS slow cook-off test
	7(g)	1.6 Article external fire test
	7(h)	1.6 Article slow cook-off test
	7(j)	1.6 Article bullet impact-off test
	7(k)	1.6 Article stack test

(*Continued*)

Explosives

Comparison

The HCS has only one hazard category for explosives and the GHS has six hazard categories. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
	Definition
	Explosive substance means a solid or liquid substance (or mixture of substances) that is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. Pyrotechnic substances are included even when they do not evolve gases.
	Criteria
	Substances, mixtures, and articles of this class are assigned to one of six divisions, 1.1 to 1.6, depending on the type of hazard they present: Division 1.1: Substances and articles that have a mass explosion hazard (a mass explosion is one that affects almost the entire load virtually instantaneously)
	Division 1.2: Substances and articles that have a projection hazard but not a mass explosion hazard
	Division 1.3: Substances and articles that have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard:
	(i) Combustion of which gives rise to considerable radiant heat
	(ii) Which burn one after another, producing minor blast or projection effects or both
	Division 1.4: Substances and articles that present no significant hazard: Substances and articles that present only a small hazard in the event of ignition or initiation. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire shall not cause a virtually instantaneous explosion of almost the entire contents of the package.
	Division 1.5: Very insensitive substances that have a mass explosion hazard: substances that have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions
	Division 1.6: Extremely insensitive articles that do not have a mass explosion hazard: articles that contain only extremely insensitive detonating substances and that demonstrate a negligible probability of accidental initiation or propagation
	NOTE: Substances that are too unstable for allocation to the above divisions are also to be classified as explosive.

Flammable Gases

Comparison

The HCS has one hazard category for flammable gases. The GHS has two hazard categories. The HCS does not require testing and does not specify test methods.

HCS Criteria	GHS Criteria
Test Method HCS has no test method. **Definition** "Gas, flammable" means: (A) A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% by volume or less (B) A gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of the lower limit	**Test Method** ISO 10156:1996 **Definition** Flammable gas means a gas having a flammable range with air at 20°C and a standard pressure of 101.3 kPa. **Criteria** Substance sand mixtures of this hazard class are assigned to one of two hazard categories on the basis of the outcome of the test or calculation method: 1. Gases, which at 20°C and a standard pressure of 101.3kPa: (a) are ignitable when in a mixture of 13% or less by volume in air; or 2. Have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit 3. Gases, other than those of category 1, which, at 20°C and a standard pressure of 101.3 kPa, have a flammable range while mixed in air.

Flammable Aerosols

Comparison

The HCS has one hazard class/category for flammable aerosols. The GHS has two hazard categories. The HCS does not require testing.

HCS Criteria	GHS Criteria
Test Method 16 CFR 1500.45 **Definition** "Aerosol, flammable" means an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening.	**Test Method** GHS Document Annex 11 **Definition** *Aerosols* means any nonrefillable receptacles made of metal, glass, or plastics and containing a gas compressed, liquefied, or dissolved under pressure, with or without a liquid, paste, or powder, and fitted with a release device allowing the contents to be ejected as solid or liquid particles in suspension in a gas, as a foam, paste, or powder or in a liquid state or in a gaseous state. Aerosol includes aerosol dispensers. **Criteria** Substances and mixtures of this hazard class are assigned to one of two hazard categories on the basis of their components, that is, flammable liquids (see GHS Chapter 2.6), flammable gases (see GHS Chapter 2.2), flammable solids (see GHS Chapter 2.7), and, if applicable, the results of the foam test (for foam aerosols) and of the ignition distance test and enclosed space test (for spray aerosols): Note: Flammable components do not cover pyrophoric, self-heating, or water-reactive substances because such components are never used as aerosol contents. The chemical heat of combustion (DHc), in kilojoules per gram (kJ/g), is the product of the theoretical heat of combustion (D Hcomb), and a combustion efficiency, usually less than 1.0 a typical combustion efficiency is 0.95 or 95%). For a composite aerosol formulation, the chemical heat of combustion is the summation of the weighted heats of combustion for the individual components, as follows: DH_c (product) = S[I% × $DH_{c(I)}$] where DH_c = chemical heat of combustion (kJ/g) I% = weight fraction of component I in the product $DH_{c(I)}$ = chemical heat of combustion of component I (kJ/g). The chemical heats of combustion can be found in literature, calculated, or determined by tests (see ASTM D 240, ISO/FDIS 13943:1999 (E/F) 86.1 to 86.3 and NFPA30B).

Oxidizing Gases

Comparison

The HCS covers oxidizers as a class of chemicals with one category. The GHS The HCS does not require testing or specify test methods. covers oxidizers by physical state with one hazard category for gases.

HCS Criteria	GHS Criteria
Test Method	**Test Method**
HCS has no test method.	ISO 10156:1996
Definition	**Definition**
"Oxidizer" means a chemical other than a blasting agent or explosive as defined in 1910.109(a) that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.	Oxidizing gas means any gas that may, generally by providing oxygen, cause or contribute to the combustion of other material more than air does.
	Criteria
	Substances and mixtures of this hazard class are assigned to a single hazard category on the basis that, generally by providing oxygen, they cause or contribute to the combustion of other material more than air does.

Gases under Pressure

Comparison

The HCS has one hazard class/category for compressed gases. The GHS uses physical state as a basis for four groups. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method HCS has no test method. **Definition** "Compressed gas" means i. A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C) ii. A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C) iii. A liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72	**Test Method** For this group of gases, the following information is required to be known: The vapor pressure at 50°C The physical state at 20°C at standard ambient pressure The critical temperature Data can be found in literature, calculated, or determined by testing. Most pure gases are already classified in the UN Model Regulations. **Criteria** Gases are classified, according to their physical state when packaged, into one of four groups as follows: *Compressed gases* A gas that when packaged under pressure is entirely gaseous at −50°C, including all gases with a critical temperature <−50°C *Liquefied gases* A gas that when packaged under pressure is partially liquid at temperatures above −50°C. A distinction is made between i. High-pressure liquefied gas: a gas with a critical temperature between −50°C and +65°C ii. Low-pressure liquefied gas: a gas with a critical temperature above + 65°C *Refrigerated liquefied gases* A gas that when packaged is made partially liquid because of its low temperature *Dissolved gases* A gas that when packaged under pressure is dissolved in a liquid-phase solvent Note: The critical temperature is the temperature above which a pure gas cannot be liquefied, regardless of the degree of compression.

Flammable Liquids

Comparison

The HCS has two hazard categories for flammable liquids that cover the same flash point range as the four GHS categories. The HCS does not require testing.

HCS Criteria	GHS Criteria
Test Method Flash point: i. Tagliabue Closed Tester (See American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24-1979 (ASTM D 56-79)) for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100°F (37.8°C) that do not contain suspended solids and do not have a tendency to form a surface film under test ii. Pensky–Martens Closed Tester (see American National Standard Method of Test for Flash Point by Pensky–Martens Closed Tester, Z11.7-1979 (ASTM D 93-79)) for liquids with a viscosity equal to or greater than 45 SUS at 100°F (37.8°C), or that contain suspended solids, or that have a tendency to form a surface film under test iii. Setaflash Closed Tester (see American National Standard Method of Test for Flash Point by Setaflash Closed Tester (ASTM D3278-78)) **Definition** "Liquid, flammable" means any liquid having a flash point below 100°F (37.8°C), except any mixture having components with flash points of 100°F (37.8°C) or higher, the total of which make up 99% or more of the total volume of the mixture.	**Test Method** Flash point is determined by closed cup methods as provided in GHS Chapter 2.5, paragraph 11. Initial boiling point is also required. **Definition** Flammable liquid means a liquid having a flash point of not more than 93°C. **Criteria** Substances and mixtures of this hazard class are assigned to one of four hazard categories on the basis of the flash point and boiling point: 1. Flash point <23°C and initial boiling point <35°C 2. Flash point < 23°C and initial boiling point >35°C 3. Flash point >23°C and <60°C 4. Flash point > 60°C and <93°C Note 1: Gas oils, diesel, and light heating oils in the flash point range of 55°C to 75°C may be regarded as a special group for some regulatory purposes. Note 2: Liquids with a flash point of more than 35°C may be regarded as nonflammable liquids for some regulatory purposes (e.g., transport) if negative results have been obtained in the sustained combustibility test L.2 of the UN Manual of Tests and Criteria Part III. Note 3: Viscous flammable liquids such as paints, enamels, lacquers, varnishes, adhesives, and polishes may be regarded as a special group for some regulatory purposes (e.g., transport). The classification or the decision to consider these liquids as nonflammable may be determined by the pertinent regulation or competent authority.

Flammable Solids

Comparison

The HCS has one hazard class/category for flammable solids. The GHS has two hazard categories. The HCS does not require testing.

HCS Criteria	GHS Criteria
Test Method	**Test Method**
16 CFR 1500.44	UN Manual of Tests and Criteria Part III Test N.1
Definition	**Definition**
"Solid, flammable" means a solid, other than a blasting agent or explosive as defined in 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.	Flammable solid means a solid that is readily combustible or may cause or contribute to fire through friction.
	Criteria
	Substances and mixtures of this hazard class are assigned to one of two hazard categories on the basis of the outcome of the test:
	1. Burning rate test:
	Substances other than metal powders:
	Wetted zone does not stop fire
	Burning time <45 s or burning rate >2.2 mm/s
	Metal powders:
	Burning time <5 min
	$r > 2$ Burning rate test:
	Substances other than metal powders:
	Wetted zone stops the fire for at least 4 min
	Burning time <45 s or burning rate >2.2 mm/s
	Metal powders:
	Burning time >5 min and <10 min

Self-Reactive Substances

Comparison

The HCS has only one hazard category for self-reactive (unstable/reactive) substances. The GHS has seven hazard categories. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method HCS has no test method. **Definition** "Unstable (reactive)" means a chemical that in the pure state, or as produced or transported, will vigorously polymerize, decompose, or condense or will become self-reactive under conditions of shock, pressure, or temperature.	**Test Method** UN Manual of Tests and Criteria Part II Test Series A to H Recommended tests for Self-Reactive Substance A.6 UN detonation test B.1 Detonation test in package C.1 Time/pressure test C.2 Deflagration test D.1 Deflagration test in the package E.1 Koenen test E.2 Dutch pressure vessel test F.4 Modified Trauzl test G.1 Thermal explosion test in package H.1 United States SADT test (for packages) H.2 Adiabatic storage test (for packages, etc.) H.4 Heat accumulation storage test (for packages, IBCs, and small tanks) Preliminary Safety Assessment Tests Falling weight test for impact sensitivity Friction or impacted friction test for friction sensitivity Test to assess thermal stability and the exothermic decomposition energy Test to assess the effect of ignition **Definition** Self-reactive substance means a thermally unstable liquid or solid substance liable to undergo a strongly exothermic decomposition even without participation of oxygen (air). This definition excludes substances or mixtures classified under the GHS as explosive, organic peroxides or as oxidizing.

(*Continued*)

Self-Reactive Substances

Comparison

The HCS has only one hazard category for self-reactive (unstable/reactive) substances. The GHS has seven hazard categories. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
	Criteria Substances and mixtures of this hazard class are assigned to one of the seven "types" A to G on the basis of the outcome of the tests. Any self-reactive substance should be considered for classification in this class unless (a) They are explosives, according to the GHS criteria of Chapter 2.1 (b) They are oxidizing substances, according to the GHS criteria of Chapter 2.13 or 2.14 (c) They are organic peroxides, according to the GHS criteria of Chapter 2.15 (d) Their heat of decomposition is <300 J/g (e) Their self-accelerating decomposition temperature (SADT) is >75°C for a 50-kg package Self-reactive substances are classified in one of the seven categories of "types A to G" for this class, according to the following principles: (A) Any self-reactive substance that can detonate or deflagrate rapidly, as packaged, will be defined as self-reactive substance **Type A.** (B) Any self-reactive substance possessing explosive properties and which, as packaged, neither detonates nor deflagrates rapidly, but is liable to undergo a thermal explosion in that package will be defined as self-reactive substance **Type B.** (C) Any self-reactive substance possessing explosive properties when the substance as packaged cannot detonate or deflagrate rapidly or undergo a thermal explosion will be defined as self-reactive substance **Type C.** (D) Any self-reactive substance that in laboratory testing i. Detonates partially, does not deflagrate rapidly, and shows no violent effect when heated under confinement; ii. Does not detonate at all, deflagrates slowly, and shows no violent effect when heated under confinement; iii. Does not detonate or deflagrate at all and shows a medium effect when heated under confinement; will be defined self-reactive substance **Type D.** (E) Any self-reactive substance that, in laboratory testing, neither detonates nor deflagrates at all and shows low or no effect when heated under confinement will be defined as self-reactive substance **Type E**.

(*Continued*)

Self-Reactive Substances

Comparison

The HCS has only one hazard category for self-reactive (unstable/reactive) substances. The GHS has seven hazard categories. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
	(F) Any self-reactive substance that, in laboratory testing, neither detonates in the cavitated state nor deflagrates at all and shows only a low or no effect when heated under confinement as well as low or no explosive power will be defined self-reactive substance **Type F.**
	(G) Any self-reactive substance that, in laboratory testing, neither detonates in the cavitated state nor deflagrates at all and shows no effect when heated under confinement nor any explosive power, provided that it is thermally stable (self-accelerating decomposition temperature is 60°C to 75°C for a 50-kg package), and, for liquid mixtures, a diluent having a boiling point not less than 150°C is used for desensitization will be defined as self-reactive substance **Type G**. If the mixture is not thermally stable or a diluent having a boiling point less than 150°C is used for desensitization, the mixture shall be defined self-reactive substance **Type F.**

Pyrophoric Liquids

Comparison

The HCS has one hazard class/category for pyrophorics. The GHS covers pyrophorics by physical state with one hazard category for pyrophoric liquids. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method HCS has no test method.	**Test Method** UN Manual of Tests and Criteria Part III Test N.3
Definition "Pyrophoric" means a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.	**Definition** Pyrophoric liquid means a liquid that, even in small quantities, is liable of igniting within 5 min after coming into contact with air. **Criteria** Substances and mixtures of this hazard class are assigned to a single hazard category on the basis of the outcome of the test: The liquid ignites within 5 min when added to an inert carrier and exposed to air, or it ignites or chars a filter paper on contact with air within 5 min.

Pyrophoric Solids

Comparison

The HCS has one hazard class/category for pyrophorics. The GHS covers pyrophorics by physical state with one hazard category for pyrophoric liquids. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method HCS has no test method.	**Test Method** UN Manual of Tests and Criteria Part III Test N.2
Definition "Pyrophoric" means a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.	**Definition** Pyrophoric solid means a solid that, even in small quantities, is liable of igniting within 5 min after coming into contact with air. **Criteria** Substances and mixtures this hazard class are assigned to a single hazard category on the basis of the outcome of the test: The solid ignites within 5 min of coming into contact with air.

Self-Heating Substances

Comparison

The HCS does not have this exact hazard class. According to the GHS building blocks, OSHA will need to determine if this hazard class will be in the HCS. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method	**Test Method**
HCS has no test method.	UN Manual of Tests and Criteria Part III Test N.4
Definition	**Definition**
"Unstable (reactive)" means a chemical that in the pure state, or as produced or transported, will vigorously polymerize, decompose, or condense, or will become self-reactive under conditions of shock, pressure or temperature.	Self-heating substance means a solid or liquid substance, other than a pyrophoric substance, that, by reaction with air and without energy supply, is liable to self-heat; this substance differs from a pyrophoric substance in that it will ignite only when in large amounts (kilograms) and after long periods of time (hours or days).
Or	**Criteria**
"Pyrophoric" means a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.	Substances and mixtures of this hazard class are assigned to one of two hazard categories on the basis of the outcome of the test: 1. A positive result is obtained in a test using a 25-mm sample cube at 140°C. 2. (a) A positive result is obtained in a test using a 100-mm sample cube at 140°C and a negative result is obtained in a test using a 25-mm cube sample at 140°C, and the substance is to be packed in packages with a volume of more than 3 m^3. (b) A positive result is obtained in a test using a 100-mm sample cube at 140°C and a negative result is obtained in a test using a 25-mm cube sample at 140°C; a positive result is obtained in a test using a 100-mm cube sample at 120°C, and the substance is to be packed in packages with a volume of more than 450 L. (c) A positive result is obtained in a test using a 100-mm sample cube at 140°C and a negative result is obtained in a test using a 25-mm cube sample at 140°C and a positive result is obtained in a test using a 100-mm cube sample at 100°C.

Substances that on Contact with Water Emit Flammable Gases

Comparison
The HCS has one hazard class/category for water reactive substances. The GHS has three hazard categories. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method	**Test Method**
HCS has no test method.	UN Manual of Tests and Criteria Part III Test N.5
Definition	**Definition**
	Substances that, on contact with water, emit flammable gases means a solid or liquid substance or mixture that, by interaction with water, is liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.
"Water-reactive" means a chemical that reacts with water to release a gas that is either flammable or presents a health hazard.	**Criteria** Substances and mixtures of this hazard class are assigned to one of three hazard categories on the basis of the outcome of the test: 1. Any substance that reacts vigorously with water at ambient temperatures and demonstrates generally a tendency for the gas produced to ignite spontaneously or that reacts readily with water at ambient temperatures such that the rate of evolution of flammable gas is equal to or greater than 10 L/kg of substance over any 1 min. 2. Any substance that reacts readily with water at ambient temperatures such that the maximum rate of evolution of flammable gas is equal to or greater than 20 L/kg of substance per hour and that does not meet the criteria for category 1. 3. Any substance that reacts slowly with water at ambient temperatures such that the maximum rate of evolution of flammable gas is equal to or greater than 1 L/kg of substance per hour and that does not meet the criteria for categories 1 and 2.

Oxidizing Liquids

Comparison

The HCS covers oxidizers as a class of chemicals with one category. The GHS covers oxidizers by physical state with three hazard categories for liquids. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method	**Test Method**
HCS has no test method.	UN Manual of Tests and Criteria Part III Test O.2
Definition	**Definition**
"Oxidizer" means a chemical other than a blasting agent or explosive as defined in 1910.109(a) that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.	Oxidizing liquid means a liquid that, while in itself not necessarily combustible, may, generally by yielding oxygen, cause or contribute to the combustion of other material.
	Criteria
	Substances and mixtures of this hazard class are assigned to one of three hazard categories on the basis of the outcome of the test: 1. Any substance that, in the 1:1 mixture, by mass, of substance and cellulose tested, spontaneously ignites; or the mean pressure rise time of a 1:1 mixture, by mass, of substance and cellulose is less than that of a 1:1 mixture, by mass, of 50% perchloric acid and cellulose. 2. Any substance that, in the 1:1 mixture, by mass, of substance and cellulose tested, exhibits a mean pressure rise time less than or equal to the mean pressure rise time of a 1:1 mixture, by mass, of 40% aqueous sodium chlorate solution and cellulose, and the criteria for category 1 are not met. 3. Any substance that, in the 1:1 mixture, by mass, of substance and cellulose tested, exhibits a mean pressure rise time less than or equal to the mean pressure rise time of a 1:1 mixture, by mass, of 65% aqueous nitric acid and cellulose, and the criteria for category 1 and 2 are not met.

Oxidizing Solids

Comparison

The HCS covers oxidizers as a class of chemicals with one category. The GHS covers oxidizers by physical state with three hazard categories for solids. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method HCS has no test method. **Definition** "Oxidizer" means a chemical other than a blasting agent or explosive as defined in 1910.109(a) that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.	**Test Method** UN Manual of Tests and Criteria Part III Test O.1 **Definition** Oxidizing solid means a solid that, while in itself not necessarily combustible, may, generally by yielding oxygen, cause or contribute to the combustion of other material. **Criteria** Substances and mixtures of this hazard class are assigned to one of three hazard categories on the basis of the outcome of the test: 1. Any substance that, in the 4:1 or 1:1 sample-to-cellulose ratio (by mass) tested, exhibits a mean burning time less than the mean burning time of a 3:2 mixture, by mass, of potassium bromate and cellulose. 2. Any substance that, in the 4:1 or 1:1 sample-to-cellulose ratio (by mass) tested, exhibits a mean burning time equal to or less than the mean burning time of a 2:3 mixture (by mass) of potassium bromate and cellulose, and the criteria for category 1 are not met. 3. Any substance that, in the 4:1 or 1:1 sample-to-cellulose ratio (by mass) tested, exhibits a mean burning time equal to or less than the mean burning time of a 3:7 mixture (by mass) of potassium bromate and cellulose, and the criteria for categories 1 and 2 are not met

Organic Peroxides

Comparison

The HCS covers organic peroxides as a class of chemicals with one category. The GHS has seven hazard categories for organic peroxides. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
Test Method HCS has no test method. **Definition** "Organic peroxide" means an organic compound that contains the bivalent -O-O- structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms have been replaced by an organic radical.	**Test Method** UN Manual of Tests and Criteria Part II Test Series A to H Recommended tests for Organic Peroxides A.6 UN detonation test B.1 Detonation test in package C.1 Time/pressure test C.2 Deflagration test D.1 Deflagration test in the package E.1 Koenen test E.2 Dutch pressure vessel test F.4 Modified Trauzl test G.1 Thermal explosion test in package H.1 United States SADT test (for packages) H.2 Adiabatic storage test (for packages, etc.) H.4 Heat accumulation storage test (for packages, IBCs, and small tanks) Preliminary Safety Assessment Tests Falling weight test for impact sensitivity Friction or impacted friction test for friction sensitivity Test to assess thermal stability and the exothermic decomposition energy Test to assess the effect of ignition

(*Continued*)

Organic Peroxides

Comparison

The HCS covers organic peroxides as a class of chemicals with one category. The GHS has seven hazard categories for organic peroxides. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
	Definition Organic peroxide means a liquid or solid organic substance which contains the bivalent -O-O- structure and may be considered a derivative of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals. The term also includes organic peroxide formulation (mixtures). **Criteria** Substances and mixtures of this hazard class are assigned to one of the seven "types" A to G on the basis of the outcome of the tests: Any organic peroxide is considered for classification in this class, unless it contains (a) Not more than 1.0% available oxygen from the organic peroxides when containing not more than 1.0% hydrogen peroxide (b) Not more than 0.5% available oxygen from the organic peroxides when containing more than 1.0% but not more than 7.0% hydrogen peroxide Note: The available oxygen content (%) of an organic peroxide mixture is given by the formula: $16 \times S\ (n_i \times c_i/m_i)$ where n_i= number of oxygen groups per molecule of organic peroxide i c_i = concentration (mass%) of organic peroxide i m_i = molecular mass of organic peroxide i Organic peroxides are classified in one of the seven hazard categories of "types A to G" for this class, according to the following principles: (A) Any organic peroxide mixture that can detonate or deflagrate rapidly, as packaged, will be defined as organic peroxide **Type A.** (B) Any organic peroxide mixture possessing explosive properties and which, as packaged, neither detonates nor deflagrates rapidly, but is liable to undergo a thermal explosion in that package will be defined as organic peroxide **Type B.**

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Organic Peroxides

Comparison

The HCS covers organic peroxides as a class of chemicals with one category. The GHS has seven hazard categories for organic peroxides. The value of multiple hazard categories for the workplace should be addressed. The HCS does not require testing or specify test methods.

HCS Criteria	GHS Criteria
	(C) Any organic peroxide mixture that is in laboratory testing i. Detonates partially, does not deflagrate rapidly, and shows no violent effect when heated under confinement; ii. Does not detonate at all, deflagrates slowly, and shows no violent effect when heated under confinement; iii. Does not detonate or deflagrate at all and shows a medium effect when heated under confinement; will be defined as organic peroxide **Type D.** (D) Any organic peroxide mixture that, in laboratory testing, neither detonates nor deflagrates at all and shows low or no effect when heated under confinement will be defined as organic peroxide **Type E.** (E) Any organic peroxide mixture that, in laboratory testing, neither detonates in the cavitated state nor deflagrates at all and shows only a low or no effect when heated under confinement as well as low or no explosive power will be defined as organic peroxide **Type F.** (F) Any organic peroxide mixture that, in laboratory testing, neither detonates in the cavitated state nor deflagrates at all and shows no effect when heated under confinement nor any explosive power, provided that it is thermally stable (self-accelerating decomposition temperature is 60°C or higher for a 50-kg package), and, for liquid mixtures, a diluent having a boiling point of not less than 150°C is used for desensitization, will be defined as organic peroxide **Type G**. If the mixture is not thermally stable or a diluent having a boiling point of less than 150°C is used for desensitization, the mixture shall be defined as organic peroxide **Type F**. Note 1: Type G has no hazard communication elements assigned but should be considered for properties belonging to other hazard classes. Note 2: Types A to G may not be necessary for all systems.

Substances Corrosive to Metal

Comparison

The HCS does not regulate substances corrosive to metal. According to the GHS building block approach, OSHA needs to determine if the HCS will cover this hazard class in the future. The HCS does not have required testing or specified test methods.

HCS Criteria	GHS Criteria
Test Method	**Test Method:**
HCS has no test method or criteria/definition.	Steel: ISO9328 (II): 1991—Steel type P235
Definition	Aluminum: ASTM G31-72 (1990)—non-clad types 7075-T6 or AZ5GU-T66
HCS does not cover this classification. HCS Appendix A states: This term shall not refer to action on inanimate surfaces.	**Definition**
	Corrosive to metal means a substance or a mixture that by chemical action will materially damage, or even destroy, metals.
	Criteria
	Corrosion rate on steel or aluminum surfaces exceeding 6.25 mm/year at a test temperature of 55°C.
	A substance that is corrosive to metal is classified in a single hazard category for this class on the basis of the test.

Comparison of Label Elements

General Comments

- The HCS label requirements are totally performance oriented.
- The GHS labeling requirements are specified: signal words, hazard statements, and pictograms.
- The use of pictograms is a significant change for US workplace labeling.
- If the HCS retains NTP/OSHA/IARC carcinogens, guidance on labeling could be a useful tool.
- US liability concerns are a label consideration.

As part of the HCS–GHS label comparison, a table of GHS pictograms and several examples of ANSI Z129.1 Hazardous Industrial Chemicals–Precautionary Labeling and GHS labels are provided.

Label Elements

Comparison

For each GHS hazard class, detailed GHS label elements (symbol, signal word, hazard statement) have been assigned to the hazard categories (subcategories). Hazard categories reflect the harmonized classification criteria. A summary of the allocation of label elements is provided in GHS Annex 1. There are special arrangements, which apply to the use of certain mixture concentrations in the GHS.

The performance-oriented nature of the OSHA HCS is particularly relevant in the labeling provisions. Implementation of specified GHS elements for all hazard classes and categories will be a major change to the HCS. The HCS requires the "identity" on labels. See the competent authority allowances discussion on product identifier.

HCS	GHS
(f)(1)(i) Identity of the hazardous chemical(s) "Identity" means any chemical or common name that is indicated on the material safety data sheet (MSDS) for the chemical. The identity used shall permit cross-references to be made among the required list of hazardous chemicals, the label, and the MSDS. "Chemical name" means the scientific designation of a chemical in accordance with the nomenclature system developed by the International Union of Pure and Applied Chemistry (IUPAC) or the Chemical Abstracts Service (CAS) rules of nomenclature, or a name that will clearly identify the chemical for the purpose of conducting a hazard evaluation. "Common name" means any designation or identification such as code name, code number, trade name, brand name, or generic name used to identify a chemical other than by its chemical name.	**Product identifier** (i) A product identifier should be used on a GHS label and it should match the product identifier used on the SDS. Where a substance or mixture is covered by the UN Model Regulations on the Transport of Dangerous Goods, the UN proper shipping name should also be used on the package. (ii) The label for a substance should include the chemical identity of the substance. For mixtures or alloys, the label should include the chemical identities of all ingredients or alloying elements that contribute to acute toxicity, skin corrosion or serious eye damage, germ cell mutagenicity, carcinogenicity, reproductive toxicity, skin or respiratory sensitization, or Target Organ Systemic Toxicity (TOST), when these hazards appear on the label. Alternatively, the competent authority may require the inclusion of all ingredients or alloying elements that contribute to the hazard of the mixture or alloy. (iii) Where a substance or mixture is supplied exclusively for workplace use, the competent authority may choose to give suppliers discretion to include chemical identities on the SDS, in lieu of including them on labels. (iv) The competent authority rules for CBI take priority over the rules for product identification. This means that where an ingredient would normally be included on the label, if it meets the competent authority criteria for CBI, its identity does not have to be included on the label.

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Label Elements

Comparison

For each GHS hazard class, detailed GHS label elements (symbol, signal word, hazard statement) have been assigned to the hazard categories (subcategories). Hazard categories reflect the harmonized classification criteria. A summary of the allocation of label elements is provided in GHS Annex 1. There are special arrangements, which apply to the use of certain mixture concentrations in the GHS.

The performance-oriented nature of the OSHA HCS is particularly relevant in the labeling provisions. Implementation of specified GHS elements for all hazard classes and categories will be a major change to the HCS. The HCS requires the "identity" on labels. See the competent authority allowances discussion on product identifier.

HCS	GHS
	Signal word A signal word means a word used to indicate the relative level of severity of hazard and alert the reader to a potential hazard on the label. The signal words used in the GHS are "Danger" and "Warning." "Danger" is used for the more severe hazard categories (i.e., the main hazard categories 1 and 2), while "Warning" is used for the less severe. The tables for each hazard class detail the signal words that have been assigned to each of the hazard categories of the GHS.
(f)(1)(ii) Appropriate hazard warnings "Hazard warning" means any words, pictures, symbols, or combination thereof appearing on a label or other appropriate form of warning that convey the specific physical and health hazard(s), including target organ effects, of the chemical(s) in the container(s).	**Hazard statement** A hazard statement means a phrase assigned to a hazard class and category that describes the nature of the hazards of a hazardous product, including, where appropriate, the degree of hazard. The tables of label elements for each hazard class detail the hazard statements that have been assigned to each of the hazard categories of the GHS. **Hazard pictogram** A pictogram means a graphical composition that includes a symbol plus other graphic elements, such as a border, background pattern, or color, that is intended to convey specific information. There are nine symbols used in the pictograms: flame, flame over circle, exploding bomb, corrosion, gas cylinder, skull and crossbones, exclamation point, environment, and new health hazard. See table. All hazard pictograms used in the GHS should be in the shape of a square set at a point.

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Label Elements

Comparison

For each GHS hazard class, detailed GHS label elements (symbol, signal word, hazard statement) have been assigned to the hazard categories (subcategories). Hazard categories reflect the harmonized classification criteria. A summary of the allocation of label elements is provided in GHS Annex 1. There are special arrangements, which apply to the use of certain mixture concentrations in the GHS.

The performance-oriented nature of the OSHA HCS is particularly relevant in the labeling provisions. Implementation of specified GHS elements for all hazard classes and categories will be a major change to the HCS. The HCS requires the "identity" on labels. See the competent authority allowances discussion on product identifier.

HCS	GHS
	Pictograms prescribed by the GHS but not the UN Recommendations on the Transport of Dangerous Goods, Model Regulations, should have a black symbol on a white background with a red frame sufficiently wide to be clearly visible. However, when such a pictogram appears on a label for a package that will not be exported, the competent authority may choose to give suppliers and employers discretion to use a black border. In addition, competent authorities may allow the use of UN Recommendations on the Transport of Dangerous Goods, Model Regulations pictograms in other use settings where the package is not covered by the Model Regulations. Pictograms prescribed by the UN Recommendations on the Transport of Dangerous Goods, Model Regulations, will use a background and symbol color as specified by those regulations. **Precautionary statements and pictograms** A precautionary statement means a phrase (and/or pictogram) that describes recommended measures that should be taken to minimize or prevent adverse effects resulting from exposure to a hazardous product, or improper storage or handling of a hazardous product. The GHS label should include appropriate precautionary information, the choice of which is with the labeler or the competent authority. Annex 3 contains examples of precautionary statements, which can be used, and also examples of precautionary pictograms, which can be used.
(f)(1)(iii) Name and address of the chemical manufacturer, importer, or other responsible party	**Supplier identification** The name, address, and telephone number of the manufacturer or supplier of the substance or mixture should be provided on the label.

GHS and Transport Pictograms

General Comments

- The GHS pictograms are provided to assist in evaluating the GHS label elements.
- The transport pictograms are included to show the variation in background and color.

GHS Pictograms and Hazard Classes



- Explosives
- Self-reactives
- Organic peroxides



- Flammables
- Self-reactives
- Pyrophorics
- Self-heating
- Emits flammable gas



- Oxidizers
- Organic peroxides



- Gases under pressure



- Acute toxicity



- Acute toxicity
- Skin irritation
- Eye irritation
- Skin sensitizers



- Carcinogens
- Respiratory sensitizers
- Reproductive toxicity
- Target organ toxicity
- Germ cell mutagens



- Eye corrosion
- Skin corrosion
- Corrosive to metal



- Aquatic toxicity

Physical and Environmental Hazard Symbols

Hazard	Transport Symbols
Explosive	
Flammability: liquid, solid, gas, pyrophoric, emit flammable gas	
Oxidizer Organic peroxide	
Gases under pressure	
Corrosive to metals	
Environmental	

Label Examples

The GHS label requirements are a significant change from performance-oriented HCS labels. Examples can be useful visual illustrations to understand what is being described verbally. Several label examples are included in this comparison. The ANSI Z 129.1, Hazardous Industrial Chemicals—Precautionary Labeling, label format has been used for the OSHA HCS label format.

Example 1: Label for small workplace container (10 L) packaged inside an outer shipping container—for workplace audience

Hazards (liquid): flammable liquid, flash point = 120°F; oral LD_{50} = 275 mg/kg

Example 2:

Hazards (liquid): moderate skin and eye irritant, possible cancer hazard by inhalation

Example 3: large container (200-L drum) for transport, emergency response, and workplace audiences

Hazards (liquid mixture): classified under GHS as toxic to reproduction, category 1B, and flammable liquid, category 3. UN RTDG classification is flammable liquid—UN 1263.
Competent authorities may choose not to require disclosure of ingredient identities on the label of products intended only for workplace use.

Example 1: GHS Label

ToxiFlam



Danger!
Toxic if swallowed
Flammable liquid and vapor
Contains: XYZ
Do not taste or swallow. Get medical attention. Do not take internally. Wash thoroughly after handling. Keep away from heat, sparks, and flame. Keep the container closed. Use only with adequate ventilation.
FIRST AID
If swallowed, induce vomiting immediately, as directed by medical personnel. Never give anything by mouth to an unconscious person.
See Material Safety Data Sheet for further details regarding the safe use of this product. Company name, Address, Phone number

---

HAZARDS (Liquid): flammable liquid, flash point = 120°F; oral LD_{50} = 275 mg/kg

EXAMPLE 2: ANSI/OSHA (HCS) Label

ToxiFlam
WARNING!
HARMFUL IF SWALLOWED
FLAMMABLE LIQUID AND VAPOR
Do not taste or swallow. Get medical attention. Do not take internally. Wash thoroughly after handling. Keep away from heat, sparks, and flame. Keep the container closed. Use only with adequate ventilation.
FIRST AID
If swallowed, induce vomiting immediately, as directed by medical personnel. Never give anything by mouth to an unconscious person.
IN CASE OF FIRE, use water fog, CO_2, or alcohol foam. Water may be ineffective. Flash point = 120°F
Residue vapor may explode or ignite on ignition; do not cut, drill, grind, or weld on or near this container.
See Material Safety Data Sheet for further details regarding the safe use of this product. Company name, Address, Phone number

HAZARDS (Liquid): flammable liquid, flash point = 120°F; oral LD_{50} = 275 mg/kg

EXAMPLE 3: GHS Label

My Product
Warning!
Cause Skin And Eye Irritation
Suspected of causing cancer by inhalation
Contains: XYZ
Do not breathe vapors or mist. Use only with adequate ventilation. Avoid contact with eyes, skin, and clothing. Wash thoroughly after handling FIRST AID
EYES: Immediately flush eyes with plenty of water for at least 15 min. Get medical attention.
SKIN: In case of contact, immediately flush skin with plenty of water. Remove contaminated clothing and shoes. Wash clothing before reuse. Get medical attention if irritation develops and persists. Company name, Address, Phone number



HAZARDS (Liquid): moderate skin and eye irritant, possible cancer hazard by inhalation

EXAMPLE 2: ANSI/OSHA (HCS) Label

My Product **CAUTION!** **MAY CAUSE SKIN AND EYE IRRITATION** ATTENTION! POSSIBLE CANCER HAZARD—CONTAINS MATERIAL THAT MAY CAUSE CANCER BASED ON ANIMAL DATA Do not breathe vapors or mist. Use only with adequate ventilation. Avoid contact with eyes, skin, and clothing. Wash thoroughly after handling. FIRST AID EYES: Immediately flush eyes with plenty of water for at least 15 min. Get medical attention. SKIN: In case of contact, immediately flush skin with plenty of water. Remove contaminated clothing and shoes. Wash clothing before reuse. Get medical attention if irritation develops and persists.	INHALED: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician. INGESTION: If swallowed, DO NOT induce vomiting unless directed by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention. **SPILL OR LEAK** Take steps to contain liquid and avoid runoff to waterways and sewer. FIRE In case of fire, use water spray, foam, dry chemical, or CO_2. HANDLING AND STORAGE Keep away from strong acids and oxidizers. Do not apply air pressure, puncture, or weld on or near this container. For additional information, read Material Safety Data Sheet for this product. 24-hour emergency phone number Company name Address Phone number

HAZARDS (Liquid): moderate skin and eye irritant, possible cancer hazard by inhalation

GHS Label for large container (200-L drum) for transport, emergency response, and workplace audiences

ZZZ Red Paint UN1263 Paint

Danger!

May damage fertility or the unborn child

Highly flammable liquid and vapor

**Contains lead pigments and cellosolve acetate





Keep away from heat and ignition sources. Keep away from food and drink. Avoid contact with skin and eyes and inhalation of vapor. Wash hands thoroughly after use and before eating

FIRST AID

For skin contact, remove contaminated clothing and wash affected area thoroughly with water. If irritation develops, seek medical attention. For eye contact, immediately flush eyes with flowing water for at least 15 min and seek medical attention.

GHS Example PLC, Leeds, England. Telephone 44 999 999 9999

**Competent authorities may choose not to require disclosure or ingredient identities on the label of products intended only for workplace use.

Comparison of SDS Elements

General Comments

The GHS SDS has more extensive information requirements than the HCS, for example, transportation classifications and other pertinent product regulatory requirements. In general, medium and large companies are using a 16-section SDS format to comply with ANSI and ISO SDS standards, the EU directive, and other global SDS requirements. The GHS 16-section SDS has information requirements that smaller companies may not currently be providing on SDSs. However, information such as transportation classifications and other product regulatory information should be available.

MSDS Comparison by Section

Comparison

The MSDS information required by the HCS can be provided in any format. OSHA Form 174 is optional. The GHS SDS requires 16 sections with a specified sequence and minimum specified information. The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key difference is the GHS requirement for information that OSHA would not usually regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

GHS MSDS Sections	GHS SDS	OSHA HCS	OSHA Form 174
1. Product and company identification	• GHS product identifier • Other means of identification • Recommended use of the chemical and restrictions on use • Supplier's details (including name, address, phone number, etc.) • Emergency phone number	• Product identity same as on label • Name address and telephone number of the manufacturer, distributor, employer, or other responsible party	• Identity (as used on label and list) • Manufacturer's name • Address (number, street, city, state and zip code) • Emergency telephone number • Telephone number for information • Date prepared • Signature of preparer
2. Hazards identification	• GHS classification of the substance/mixture and any regional information • GHS label elements, including precautionary statements (hazard symbols may be provided as a graphical reproduction of the symbols in black and white or the name of the symbol, e.g., flame, skull, and crossbones) • Other hazards that do not result in classification (e.g., dust explosion hazard) or are not covered by the GHS	• Health hazards including acute and chronic effects, listing target organs or systems • Signs and symptoms of exposure • Conditions generally recognized as aggravated by exposure • Primary routes of exposure • If listed as a carcinogen by OSHA, IARC, or NTP • See Sections 5, 9, and 10 for physical hazards	• Route(s) of entry • Inhalation • Skin • Ingestion • Health hazards (acute and chronic) • Carcinogenicity • NTP • IARC • OSHA • Signs and symptoms of exposure • Medical conditions generally aggravated by exposure

(*Continued*)

MSDS Comparison by Section

Comparison

The MSDS information required by the HCS can be provided in any format. OSHA Form 174 is optional. The GHS SDS requires 16 sections with a specified sequence and minimum specified information. The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key difference is the GHS requirement for information that OSHA would not usually regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

GHS MSDS Sections	GHS SDS	OSHA HCS	OSHA Form 174
3. Composition/ information on ingredients	• Substance-chemical identity • Common name, synonyms, and so on • CAS number, EC number, and so on • Impurities and stabilizing additives that are themselves classified and that contribute to the classification of the substance • Mixture • The chemical identity and concentration or concentration ranges of all ingredients that are hazardous within the meaning of the GHS and are present above their cutoff levels. • Note: For information ingredients, the competent • authority rules for CBI take • priority over the rules for • product identification	• Chemical and common name of ingredients contributing to known hazards • For untested mixtures, the chemical and common name of ingredients at 1% or more that present a health hazard and those that present a physical hazard in the mixture • Ingredients at 0.1% or greater, if listed carcinogens	• Hazardous components (specific chemical identity, common name(s)) • OSHA PEL • ACGIHTLV • Other recommended limits% (optional)
4. First-aid measures	• Description of necessary measures, subdivided according to the different • routes of exposure, that is, • inhalation, skin and eye contact, • and ingestion • Most important symptoms/effects, acute and delayed. • Indication of immediate medical attention and special treatment needed, if necessary	Emergency and first-aid procedures	• Emergency and first-aid procedures

(*Continued*)

MSDS Comparison by Section

Comparison

The MSDS information required by the HCS can be provided in any format. OSHA Form 174 is optional. The GHS SDS requires 16 sections with a specified sequence and minimum specified information. The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key difference is the GHS requirement for information that OSHA would not usually regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

GHS MSDS Sections	GHS SDS	OSHA HCS	OSHA Form 174
5. Firefighting measures	• Suitable (and unsuitable) extinguishing media • Specific hazards arising from the chemical (e.g., nature of any hazardous combustion products) • Special protective equipment and precautions for firefighters	• Flammable property information such as flash point • Physical hazards • Generally applicable control measures	• Flash point (METHOD USED) • Flammable limits • LEL, UEL • Extinguishing media • Special firefighting procedures • Unusual fire and explosion hazards
6. Accidental release measures	• Personal precautions, protective equipment, and emergency procedures • Environmental precautions • Methods and materials for containment and cleaning up	• Procedures for cleanup of spills and leaks	• Steps to be taken in case material is released or spilled
7. Handling and storage	• Precautions for safe handling • Conditions for safe storage, including any incompatibilities	• Precautions for safe handling and use, including appropriate hygienic practices	• Precautions to be taken in handling and storing • Other precautions
8. Exposure controls/ personal protection	• Control parameters, for example, occupational exposure limit values or biological limit values • Appropriate engineering controls • Individual protection measures, such as personal protective equipment	• General applicable control measures • Appropriate engineering controls and work practices • Protective measures during • maintenance and repair • Personal protective equipment • Permissible exposure levels, threshold limit values, listed by OSHA, ACGIH, or established company limits	• Respiratory protection (specify type) • Ventilation • Local exhaust • Special • Mechanical (general) • Other • Protective gloves • Eye protection • Other protective clothing or equipment • Work/hygienic practices

(*Continued*)

MSDS Comparison by Section

Comparison

The MSDS information required by the HCS can be provided in any format. OSHA Form 174 is optional. The GHS SDS requires 16 sections with a specified sequence and minimum specified information. The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key difference is the GHS requirement for information that OSHA would not usually regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

GHS MSDS Sections	GHS SDS	OSHA HCS	OSHA Form 174
9. Physical and chemical properties	• Appearance (physical state, color, etc.) • Odor • Odor threshold • pH • Melting point/freezing point • Initial boiling point and boiling range • Flash point: • Evaporation rate • Flammability (solid, gas) • Upper/lower flammability or explosive limits • Vapor pressure • Vapor density • Relative density • Solubility(ies) • Partition coefficient: n-octanol/ water: • Auto-ignition temperature • Decomposition temperature	• Physical and chemical characteristics of hazardous chemicals such as vapor pressure and density	• Boiling point • Specific gravity (H2O = 1) • Vapor pressure (mm Hg) • Melting point • Vapor density (air = 1) • Evaporation rate (butyl acetate = 1) • Solubility in water • Appearance and odor
10. Stability and reactivity	• Chemical stability • Possibility of hazardous reactions • Conditions to avoid (e.g., static discharge, shock, or vibration) • Incompatible materials • Hazardous decomposition products	• Organic peroxides, pyrophoric, unstable (reactive), or water-reactive hazards • Physical hazards, including reactivity and hazardous polymerization	• Stability (unstable/stable) • Conditions to avoid • Incompatibility (materials to avoid) • Hazardous decomposition or by-products • Hazardous polymerization • Conditions to avoid

(*Continued*)

MSDS Comparison by Section

Comparison

The MSDS information required by the HCS can be provided in any format. OSHA Form 174 is optional. The GHS SDS requires 16 sections with a specified sequence and minimum specified information. The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key difference is the GHS requirement for information that OSHA would not usually regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

GHS MSDS Sections	GHS SDS	OSHA HCS	OSHA Form 174
11. Toxicological information	• Concise but complete and comprehensible description of the various toxicological (health) effects and the available data used to identify those effects, including: • Information on the likely routes of exposure (inhalation, ingestion, skin, and eye contact) • Symptoms related to the physical, chemical, and toxicological characteristics • Delayed and immediate effects and chronic effects from short- and long-term exposure • Numerical measures of toxicity (such as acute toxicity estimates)	• See also Section 2 • Health hazards including acute and chronic effects, listing target organs or systems • Signs and symptoms of exposure • Primary routes of exposure • If listed as a carcinogen by OSHA, IARC, or NTP	• See Section 2
12. Ecological information	• Ecotoxicity (aquatic and terrestrial, where available) • Persistence and degradability • Bioaccmnulative potential • Mobility in soil • Other adverse effects	• No present requirements	
13. Disposal considerations	• Description of waste residues and information on their safe handling and methods of disposal, including any contaminated packaging	• See Section 7 • No present requirements	• Waste disposal method
14. Transport information	• UN number • UN Proper shipping name • Transport hazard class(es) • Packing group, if applicable • Marine pollutant (Y/N) • Special precautions that a user needs to be aware of or needs to comply with in connection with transport or conveyance either within or outside their premises	• No present requirements	

(*Continued*)

MSDS Comparison by Section

Comparison

The MSDS information required by the HCS can be provided in any format. OSHA Form 174 is optional. The GHS SDS requires 16 sections with a specified sequence and minimum specified information. The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key difference is the GHS requirement for information that OSHA would not usually regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

GHS MSDS Sections	GHS SDS	OSHA HCS	OSHA Form 174
15. Regulatory information	• Safety, health, and environmental regulations specific to the product in question	• No present requirements	
16. Other information	• Other information including information on preparation and revision of the SDS	• Date of preparation of MSDS or date of last change	See Section 1

Comparison of MSDS Elements

Comparison

The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key MSDS difference is the GHS requirement for information that OSHA does not regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

OSHA HCS	GHS
• Identity	• GHS product identifier • Other means of identification • Recommended use of the chemical and restrictions onuses
• Chemical and common names of substances	**Substance** • Chemical identity • Common name, synonyms, and so on • CAS number, EC number, and so on • Impurities and stabilizing additives that are themselves classified and that contribute to the classification of the substance. *Note: For information on ingredients, the competent authority rules for CBI take priority over the rules for product identification.*
Mixture • If the hazardous chemical is a mixture that has been tested as a whole to determine its hazards, the chemical and common name(s) of the ingredients that contribute to these known hazards, and the common name(s) of the mixture itself; or, • If the hazardous chemical is an admixture that has not been tested as a whole • The chemical and common name(s) of all ingredients that are health hazards and are present at >1%, except carcinogens, shall be listed at ≥ 0.1%	**Mixture** • The chemical identity and concentration or concentration ranges of all ingredients that are hazardous within the meaning of the GHS and are present above their cutoff levels. See individual health hazards for cutoff values. *Note: For information on ingredients, the competent authority rules for CBI take priority over the rules for product identification.*

(*Continued*)

Comparison of MSDS Elements

Comparison

The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key MSDS difference is the GHS requirement for information that OSHA does not regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

OSHA HCS	GHS
• The chemical and common name(s) of all ingredients that are health hazards and are present at <1% (<0.1% for carcinogens), if there is evidence that the ingredient(s) could be released from the mixture in concentrations that would exceed an established OSHA PEL or ACGIH TLV, or could present a health risk to employees • The chemical and common name(s) of all ingredients that have been determined to present a physical hazard when present in the mixture	
• Chemical and physical characteristics (vapor pressure, flash point, etc.)	• Appearance (physical state, color, etc.) • Odor • Odor threshold • pH • Melting point/freezing point • Initial boiling point and boiling range • Flash point • Evaporation rate • Flammability (solid, gas)

(*Continued*)

Comparison of MSDS Elements

Comparison

The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key MSDS difference is the GHS requirement for information that OSHA does not regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

OSHA HCS	GHS
• Physical hazards (fire, explosion, reactivity) • OSHA, IARC, NTP carcinogen • Health hazards • Signs and symptoms of exposure	• Upper/lower flammability or explosive limits • Vapor pressure • Vapor density • Relative density • Solubility(ies) • Partition coefficient: n-octanol/water • Auto-ignition temperature • Decomposition temperature • GHS classification of the substance/mixture and any national or regional information • Chemical stability • Possibility of hazardous reactions • Conditions to avoid (e.gv static discharge, shock, or vibration) • Incompatible materials • Hazardous decomposition products • GHS classification of the substance/mixture and any national or regional information • Concise but complete and comprehensible description of the various toxicological (health) effects and the available data used to identify those effects, including • Delayed and immediate effects and also chronic effects from short- and long-term exposure • Numerical measures of toxicity (such as acute toxicity estimates) • Available data used to identify those toxicological (health) effects • Most important symptoms/effects, acute and delayed • Symptoms related to the physical, chemical, and toxicological characteristics

(*Continued*)

Comparison of MSDS Elements

Comparison

The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key MSDS difference is the GHS requirement for information that OSHA does not regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

OSHA HCS	GHS
• Medical conditions aggravated	
• Primary route of entry	• Information on the likely routes of exposure (inhalation, ingestion, skin, and eye contact)
• First-aid procedures	• Description of necessary first-aid measures, subdivided according to the different routes of exposure, that is, inhalation, skin and eye contact, and ingestion • Indication of immediate medical attention and special treatment needed, if necessary
• Protective measures during maintenance	
• Precautions for safe handling	• Description of waste residues and information on their safe handling and methods of disposal, including the disposal of any contaminated packaging • Other hazards that do not result in classification (e.g., dust explosion hazard) or are not covered by the GHS • Environmental precautions
• Hygienic practices	• Personal precautions, protective equipment, and emergency procedures • Individual protection measures, such as personal protective equipment
• Personal protective equipment	• Individual protection measures, such as personal protective equipment
• OSHA PEL, ACGIH TLV, other limits	• Control parameters, for example, occupational exposure limit values or biological limit values
• General applicable control measures	• Control parameters
• Engineering controls	• Appropriate engineering controls
• Cleanup procedures for spills or leaks	• Personal precautions, protective equipment, and emergency procedures • Methods and materials for containment and cleaning up

(*Continued*)

Comparison of MSDS Elements

Comparison

The GHS SDS has minimum information requirements. The few HCS elements that are not specifically covered could be added: medical conditions aggravated and protective measures during maintenance and repair. The component disclosure requirements are different in the HCS and GHS. A key MSDS difference is the GHS requirement for information that OSHA does not regulate: transport information, ecological information, and other pertinent regulatory information in Section 15.

OSHA HCS	GHS
• Date of preparation/changes to MSDS	• Information on preparation and revision of the SDS
Name/address/phone for additional information	• Supplier's details (including name, address, phone number, etc.) • GHS label elements, including precautionary statements (hazard symbols may be provided as a graphical reproduction of the symbols in black and white or the name of the symbol, e.g., flame, skull and crossbones)
Emergency procedures	• Suitable (and unsuitable) extinguishing media • Specific hazards arising from the chemical (e.g., nature of any hazardous combustion products) • Special protective equipment and precautions for firefighters • Emergency phone number • Ecotoxicity (aquatic and terrestrial, where available) • Persistence and degradability • Bioaccumulative potential • Mobility in soil • Other adverse effects • UN number • UN Proper shipping name • Transport hazard class(es) • Packing group, if applicable • Marine pollutant (yes/no) • Special precautions that a user needs to be aware of or needs to comply with in connection with transport or conveyance either within or outside their premises • Safety, health, and environmental regulations specific for the product in question • Other information including information on preparation and revision of the SDS

5

Math Review

For many in the occupational safety and health profession, it has been several years since they were in a classroom and had to solve problems handed out by an instructor, who makes it look so easy while in the classroom. What the instructor may not remember is that students come from a wide variety of backgrounds or may not remember the basics required to completely understand the concepts being taught. The professional safety practitioner requires a solid background in mathematics to perform adequately. During the course of this book, there are numerous equations and applications that require a basic understanding of mathematics, including algebra and trigonometry. It is for this reason a math review chapter has been included. This chapter is not intended to provide a complete understanding of mathematics, but rather to serve only as a review. Some may find it very basic, while others will appreciate the review.

Order of Operations

One of the first items that must be understood is that there is an order to performing any mathematical equation. Included below is an age-old acronym and saying that can be used to remember the order of operations.

PEMDAS: "Please Excuse My Dear Aunt Sally"

Simply put, PEMDAS identifies the order of operations listed below:

1. Parentheses
2. Exponents
3. Multiplication
4. Division
5. Addition
6. Subtraction

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For example, in the following equation, there are five operations required.

Correct Method Example

4 + [–1(–2–1)]²	
= 4 + [–1(–3)]²	Solve everything inside the parentheses, including multiplication and subtraction.
= 4 + [3]²	Solve everything inside the parentheses (brackets) and then solve the exponents.
= 4 + 9	Finally, perform the addition and/or subtraction.
= 13	Final result.

If not performed in the correct order, you will get a totally different final result. See the below incorrect method.

Incorrect Method Example

4 + [–1(–2–1)]²	
= 4 + [–1(–3)]²	Solve everything inside the parentheses, including multiplication and subtraction.
= 4 + [3]²	Add 4 + 3.
= [4 + 3]²	Finally, square the sum.
= 49	Final result.

Basic Rules of Positive and Negative Numbers

Addition/Subtraction

(+) + (+) = (+)	Positive plus a positive will equal a positive.
(+) + (–) = (+ or –)	Positive plus a negative will equal a positive or negative.
(–) + (–) = (–)	Negative plus a negative will equal a negative.

Multiplication/Division

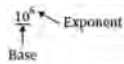
(+) × (+) = (+)	Positive times a positive will equal a positive.
(+) × (–) = (–)	Positive times a negative will equal a negative.
(–) × (–) = (+)	Negative times a negative will equal a positive.

Understanding Exponents

An exponent can be defined as a quantity representing the power to which some other quantity is raised. Exponents do not have to be numbers or

constants; they can be variables. They are often positive *whole numbers*, but they can be *negative numbers*, *fractional numbers*, *irrational numbers*, or *complex numbers*.

A number with an exponent is written as follows and contains two parts (the Base and the Exponent):



This represents the following (Figure 5.2):

$$10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1,000,000.$$

When solving for negative exponents, it will be written as

$$10^{-6}.$$

This represents the following:

$$10^{-6} = \frac{1}{10 \times 10 \times 10 \times 10 \times 10 \times 10}.$$

$$= 0.000001$$

Scientific Notation

Scientific notation (standard form) is a mathematical way to express values or numbers too large or too small to be easily written in a standard decimal notation.

For example, 392,000 can be written in scientific notation as follows (Figure 5.3):

$$3.92 \times 10^5.$$

It can also be written as 3.92 E 05, where E is representative of "×10."

Another example is the number 0.00432. Written in scientific notation, it would look like this:

$$4.32 \times 10^{-3} \text{ OR } 4.32\,\text{E} - 03.$$

Multiplication and Division Using Scientific Notation

Example

$$\frac{\left(3.21\times10^{5}\right)\left(4.88\times10^{-6}\right)}{\left(5.9\times10^{-4}\right)}$$

$$=\frac{3.21\times4.88}{5.9}$$

$$=2.65$$

For now, disregard the exponents and multiply and divide the coefficients.

Now, we will solve for the exponents. The exponents in the *numerator* (top portion) are 5 and –6, while the exponent in the *denominator* (bottom portion) is –4. Therefore, we would ADD the exponents in the numerator (5 + (–6)) and SUBTRACT the exponent in the denominator (–4), as follows:

$$5+(-6)-(-4)$$

$$=3$$

We have now solved this equation, with the result being

$$2.65\times10^{3}.$$

Engineering Notation

During the course of your professional career, you will encounter the use of engineering notation. Engineering notation is a version of scientific notation in which the power of 10 must be a multiple of three. For example, 10^6 can be written as 1000^2. Instead of writing powers of 10, the *System International* (*SI*) uses prefixes to describe numbers. An example of this is 10^{-1} or 0.01, which is described as deci in the SI system. By way of example, 0.01 (or 10^{-1}) liters of a substance is described as a *deciliter* or *dl.* Table 5.1 describes the most often encountered engineering notation terms in the safety and health profession.

TABLE 5.1

Common Engineering Notation Symbols and Prefixes

10^n	Prefix	Symbol	Decimal
10^9	giga	G	1,000,000,000
10^6	mega	M	1,000,000
10^3	kilo	k	1000
10^2	hecto	h	100
10^1	deca	d	10
10^0	None	None	1
10^{-1}	deci	d	0.1
10^{-2}	centi	c	0.01
10^{-3}	milli	m	0.001
10^{-6}	micro	μ	0.000001
10^{-9}	nano	n	0.000000001
10^{-12}	pico	p	0.000000000001

Absolute Values

The *absolute value* of any number is the value of the corresponding arithmetic number that is positive. Absolute values are represented mathematically by two enclosed bars.

For example: $|-3| = 3$.

Absolute values play a particular role when solving ventilation equations.

Logarithms

In working with logarithms, remember that there are three basic rules. These rules are identified below:

- $\log_b(mn) = \log_b(m) + \log_b(n)$
- $\log_b(m/n) = \log_b(m) - \log_b(n)$
- $\log_b(m^n) = n \times \log_b(m)$

Example 1:

$$\log(4 \times 5) = \log 4 + \log 5$$

$$\log(4 \times 5) = 0.601 + 0.699$$

$$\log(4 \times 5) = 1.299$$

Example 2:

$$\log \frac{4}{5} = \log 4 - \log 5$$

$$\log 0.8 = 0.602 - 0.6989$$

$$\log 0.8 = -0.0969$$

Example 3:

$$\log 4^5 = 5 \times \log 4$$

$$\log 4^5 = 5 \times 0.602$$

$$\log 4^5 = 3.01$$

Formula or Equation Transpositions

In any equation, the purpose is to determine the value of an unknown variable. The key step in solving for the unknown is to isolate the unknown variable to one side of the equation. Fair and equal treatment to both sides of the equation is required. In other words, do to one side as you do to the other side.

For example, solving for x in the following equation, we must first isolate x on one side by itself.

$6x + 5 = 29$	
$= 6x + 5 - 5 = 29 - 5$	Subtract 5 from both sides.
$= 6x = 24$	Now we can isolate x by dividing both sides by 6.
$= \frac{6x}{6} = \frac{24}{6}$	
$= x = 4$	The value of x = 4.

To illustrate transposition further, the following two examples, using basic safety calculations, are offered.

In the first example, we will use the ventilation equation $Q = VA$,

where

Q = volumetric rate (cubic feet per minute or cfm)
V = velocity of air (feet per minute or fpm)
A = cross-sectional area of duct (SF or ft^2)

Note: It is extremely important to pay particular attention to the units of measurement when solving safety equations. Many times, the questions on the Associate Safety Professional (ASP) or Certified Safety Professional (CSP) exams are written in different units to test your detailed knowledge and understanding. For example, the question may give you a duct measurement of 5 in. wide and 8 in. long. You will need to convert into feet in order to obtain the correct result.

A useful tool for helping to understand how transposition works in a simple three-variable calculation is shown in Figure 5.1.

Solve for A in the following case, given that the total volume of airflow is 3225 cfm and the airflow is 350 fpm. Q = 3225 cfm; V = 350 fpm; and A = ?

3225 cfm = (350 fpm) (A),	where A is the unknown.
$= \frac{3225\,\text{cfm}}{350\,\text{fpm}} = \frac{(350\,\text{fpm})(A)}{(350\,\text{fpm})}$	Isolate A by itself by dividing both sides by 350 fpm.
= 9.21 sf or ft^2.	Remember that A is represented in square feet.

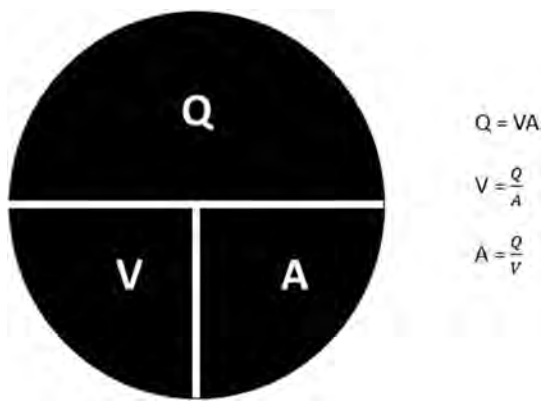


FIGURE 5.1
Illustration of simple three-variable ventilation transposition (Source: Yates, W. David, 2024).

A second example of transposition using a basic electrical equation is to solve for the amperage, given that there are 110 volts (V) and the resistance (R) is 8 ohms (Ω). The basic equation is

$$V = IR,$$

where
V = volts
I = current (measured in amperes)
R = resistance (measured in ohms or Ω)
The equation (transposition is illustrated in Figure 5.2 :
Inserting the known values into the equation, we are left with

110 V = (I)(8 Ω)	I being the unknown variable.
$= \frac{110V}{8\Omega} = \frac{(I)(8\Omega)}{(8\Omega)}$	Isolate I by itself by dividing both sides by 8 Ω.
= 13.75 A.	

Factorials

Factorials are quite simple to understand. They are products with an exclamation point, such as 6!. It simply means to multiply from 1 to the product in the factors. For example, 6! is solved as follows: 6! = 1 × 2 × 3 × 4 × 5 × 6 = 720. Perform ordinary mathematical functions using factorials as you would any other function. For example:

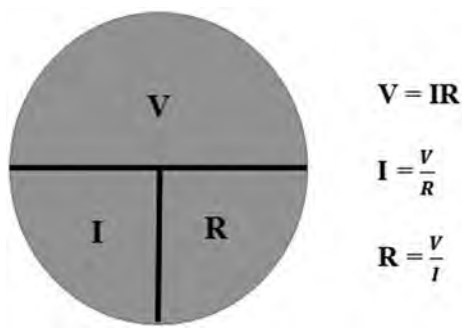


FIGURE 5.2
Illustration of simple three-variable electrical transposition (Source: Yates, W. David, 2024).

$$\frac{4!}{6!}$$

$$= \frac{1 \times 2 \times 3 \times 4}{1 \times 2 \times 3 \times 4 \times 5 \times 6}$$

$$= \frac{24}{720}$$

$$= 0.33.$$

Note: For many reasons, 0! is always 1. You should commit this to memory when working with factorials.

Euler's Number

Euler's number is a mathematical constant, which is the base of the natural logarithm. The actual number is estimated to be 2.71828 and is the limit of "n" as "n" approaches infinity. It is expressed as **"e"** and is found on scientific calculators as a function key. Depending on the calculator, it may be necessary to use the second key.

Common Geometric Equations

Throughout your career and specifically on the ASP and CSP exams, you will have the need to determine square feet, cubic feet, or other dimensions of various geometric spaces or containers. It is amazing to me that over the years, when needed, some of the basic equations have simply vanished from my mind for the moment and I've had to go to a handy reference source to review the equation. Therefore, I've included several of the basic equations to help you in your review. Many questions on the certification exams will be asked of you on the premise that you already know how to solve for the unknown and will not directly provide this information in the scenario. For example, a question may ask you to calculate the required overflow protection (dike area), given that you have two tanks measuring 4 ft in diameter and 10 ft long. In order to calculate the required capacity of the dike area, you must first determine the maximum amount of liquid potentially stored

in the tanks. Then, you must calculate the perimeter and height of the proposed dike.

Area	
Square or rectangle	L (length) × W (width)
Circle	πr^2, where π is 3.14159
Triangle	½ b (base) × h (height)

Note: Area of an object will always result in sq. ft., sq. in., or other unit of measurement.

Distance	
Circle (also called circumference)	πd (diameter) or $2\pi r$ (radius)
Square or rectangle	$2L + 2W$

Volume	
Square or rectangle	$L \times W \times H$
Cylinder	$\pi r^2 \times h$
Sphere	$4/3\pi r^3$
Cone	$\frac{\pi h r^2}{3}$

Pythagorean Equation

The *Pythagorean equation* is extremely useful in solving many problems encountered in the safety and health profession. It is used to determine the lengths of any side of a right triangle and can be used further to identify the calculated degree of any angle. Fortunately, for the exam candidate, this equation is provided on the exam reference sheet, so you will not have to commit this one to memory.

The *Pythagorean equation* is as follows:

$$a^2 + b^2 = c^2$$

Note: The hypotenuse of any right triangle is always the longest side.

A practical safety example using the *Pythagorean equation* is a ladder leaning against a building. At the base, the ladder is 4 ft from the wall. It touches the wall at the top at a height of 12 ft. How long is the ladder?

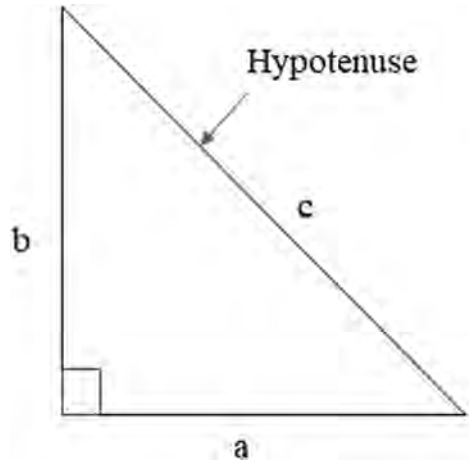


FIGURE 5.3
Right triangle (Source: Yates, W. David, 2024).

Inserting the known values into the equation, we have the following:

$$a = 4\,\text{feet}, b = 12\,\text{feet}, \text{and}\, c = ?$$

Therefore,

$4^2 + 12^2 = c^2$	
$= 16 + 144 = c^2$	There are no parentheses, so we solve for the exponents.
$= 160 = c^2$	c^2 is isolated, but we now need to solve for c by obtaining the square root of both sides of the equation.
$= \sqrt{160} = \sqrt{c^2}$	
$= 12.65$ ft $= c$	The length of the ladder is 12.65 ft.

Basic Trigonometric Functions

Trigonometry can help solve a lot of the problems seen in the certification exam or in everyday safety practice. Therefore, it is necessary to at least understand the basics of sine, cosine, tangent, arcsine, arccosine, and arccotangent. A simple way to remember the equations for each is to use **"SOH-CAH-TOA."** The abbreviations are represented as follows:

SOH

$$\text{Sine} = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

CAH

$$\text{Cos ine} = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

TOA

$$\text{Tan gent} = \frac{\text{Opposite}}{\text{Adjacent}}$$

Sine

The *sine* (*sin*) of an angle is equal to the opposite (length) divided by the hypotenuse (length). For example:

$\angle bc$ represents the angle ($\angle$) created by the intersection of sides *b* and *c* (Figure 5.4).

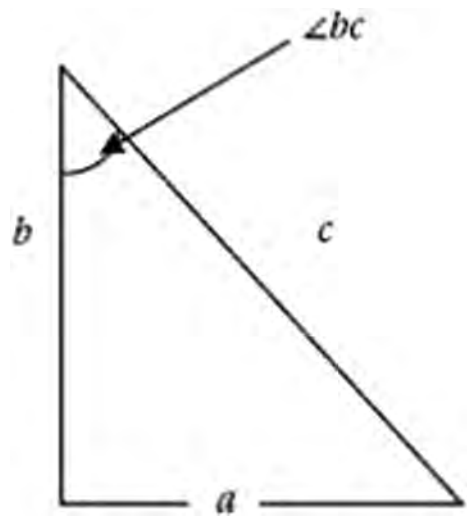


FIGURE 5.4
Sine of angle *bc* (Source: Yates, W. David, 2024).

Given the following information, solve for $\angle bc$:

$a = 3$ ft
$b = 4$ ft
$c = 5$ ft (the hypotenuse)

Using *sine* (*sin*), we input the following data into the equation:

$\sin\angle bc = \frac{3}{5}$	Remember that the sine is equal to the opposite side divided by the hypotenuse.
$\sin \angle bc = 0.6$	The sin of $\angle bc$ is 0.6. However, this does not provide us with the angle. To obtain the angle, we need to determine the arcsine.

Note: The arcsine is the inverse function of sine.

Now that we have determined that $\sin \angle bc = 0.6$, we use the inverse function (arcsine) to calculate the angle. It is usually written as arcsin or $\sin^{-1}$. By way of example, we take the $\sin \angle bc$ above, which is 0.6, and obtain the arcsin or $\sin^{-1}$. We do this by inputting 0.6 into the calculator and hitting the inverse or second key for sin, giving us an angle of 36.87° and rounding off to 37°.

Cosine

The *cosine* (*cos*) of an angle is determined by dividing the adjacent side (length) by the hypotenuse (length). Given the same data as discussed under the sine section, we can determine the angle by using the cosine function, as follows:

$\cos\angle bc = \frac{4}{5}$	Remember that the cosine is equal to the adjacent side divided by the hypotenuse.
$= \cos \angle bc = 0.8$	The sin of $\angle bc$ is 0.8. However, this does not provide us with the angle. To obtain the angle, we need to determine the arccosine.

Now that we have determined that the $\cos \angle bc = 0.8$, we use the inverse function (arccosine) to calculate the angle. It is usually written as arccos or $\cos^{-1}$. By way of example, we take the $\cos \angle bc$ above, which is 0.8 and obtain the arccos or $\cos^{-1}$. We do this by inputting 0.8 into the calculator and hitting the inverse or second key for cos, giving us an angle of 36.87° and rounding off to 37°.

Tangent

The *tangent* (*tan*) of an angle is determined by dividing the opposite side (length) by the adjacent (length). Given the same data as discussed under

the sine section, we can determine the angle by using the tangent function as follows:

$\tan\angle bc = \frac{3}{4}$	Remember that the tangent is equal to the opposite side divided by the adjacent side.
= tan $\angle bc$ = 0.75	The tan of $\angle bc$ is 0.75. However, this does not provide us with the angle. To obtain the angle, we need to determine the arctangent.

Now that we have determined that the tan $\angle bc$ = 0.8, we use the inverse function (arctangent) to calculate the angle. It is usually written as arctan or $\tan^{-1}$. By way of example, we take the tan $\angle bc$ above, which is 0.75 and obtain the arctan or $\tan^{-1}$. We do this by inputting 0.75 into the calculator and hitting the inverse or second key for tan, giving us an angle of 36.87° and rounding off to 37°.

Arcsine, Arccosine, and Arctangent

As mentioned previously, the *arcsine*, *arccosine*, and *arctangent* are all inverse functions of sine, cosine, and tangent, respectively. Mathematically, they can be written as follows:

Arcsine: arcsin = $\sin^{-1}$

Arccosine: arccos = $\cos^{-1}$

Arctangent: arctan = $\tan^{-1}$

As a practical safety application, we have a ramp that rises 4 ft in a 10 ft run. What is the angle of the ramp? (Figure 5.5)

Since we know the lengths of the adjacent side and opposite sides (remember that *c* in this case is the hypotenuse), we will solve for the tangent of $\angle ca$.

$$\tan\angle ca = \frac{4(\text{opposite})}{10(\text{adjacent})} = 0.4$$

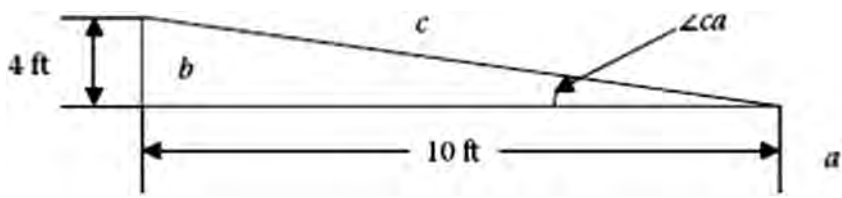


FIGURE 5.5
Practical application example (Arctangent) (Source: Yates, W. David, 2024).

or written another way:

$$\angle ca = \tan^{-1} = 0.4.$$

Now that we have determined that the tan $\angle ca = 0.4$, we use the inverse function (arctangent) to calculate the angle. It is usually written as arctan or $\tan^{-1}$. By way of example, we take the tan $\angle ca$ above, which is 0.4 and obtain the arctan or $\tan^{-1}$. We do this by inputting 0.4 into the calculator and hitting the inverse or second key for tan, giving us an angle of 21.8° and rounding off to 22°. Therefore, the ramp is on a 22° incline.

Another example calculating sling loads is as follows:

In the example as in Figure 5.6, we have an object weighing 1200 lb supported by two slings at 30° angles. We divide the weight by the number of slings (2), which is 600 lb. Now we have the weight at side *a* (the opposite). We also know that the angle is 30°. By using the sine function, we can determine the weight at each leg of the sling.

$\text{Sin}30° = \frac{600}{c}$	Isolate *c* by itself by multiplying both sides by *c*.
$= \sin 30°(c) = \frac{(600)(c)}{(c)}$	Now divide both sides by sin 30°.
$= \sin 30°(c) = 600$	Now divide both sides by sin 30°.
$= \frac{\sin 30°(c)}{\sin 30°} = \frac{600}{\sin 30°}$	
$= c = \frac{600}{\sin 30°}$	Now use the sin function key and divide 600 by 0.5.
$= c = \frac{600}{0.5}$	
$= c = 1200$	The weight on each sling is 1200 lb.

Quadratic Equation

Solving for multiple unknowns can often be difficult. It is for this reason that the safety professional must know how to calculate them using the *quadratic equation.* The quadratic equation uses the *numerical coefficients* from the following: $ax^2 + bx + c = 0$. We are simply setting each factor to 0. The value of *x* is given by the following (*quadratic equation*):

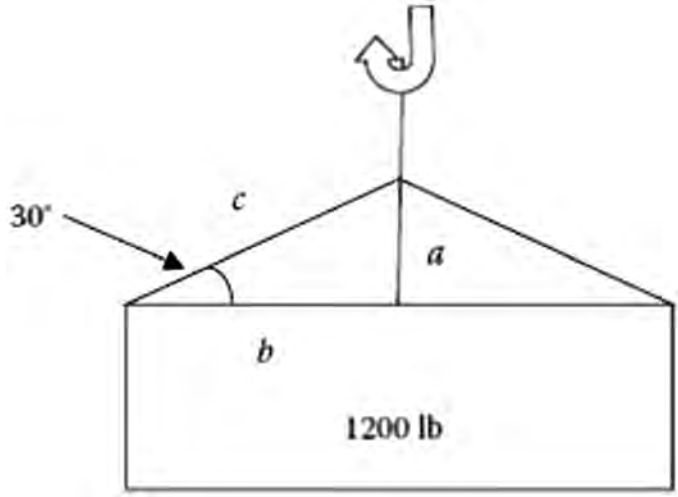


FIGURE 5.6
Sling load example using sine (Source: Yates, W. David, 2024).

$$x_1, x_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

Using $2x^2 - 4x - 3$, we can solve for x using the quadratic equation.

The coefficients are as follows: $a = (2)$, $b = (-4)$, and $c = (-3)$.

We insert the coefficients into the quadratic equation as follows:

$x_1, x_2 = \frac{-(-4) \pm \sqrt{(-4)^2 - 4(2)(-3)}}{2(2)}$	Remember the order of operations and begin solving the equation. We will solve for x.
$x_1, x_2 = \frac{4 \pm \sqrt{16 + 24}}{4}$	
$x_1, x_2 = \frac{4 \pm \sqrt{40}}{4}$	
$x_1, x_2 = \frac{4 \pm 6.32}{4}$	Complete the math and then solve for x.
$x_1 = \frac{4 \pm 6.32}{4} = \frac{10.32}{4} = 2.58$	$x_1 = 2.58$. Now we will solve for x_2.
$x_2 = \frac{4 - 6.32}{4} = \frac{-2.32}{4} = -0.58$	$x_2 = -0.58$.

Calculator

Note: *Information provided in this section is derived from the A Complete Guide to Safety Certification, Ninth Edition, April 2024, Board of Certified Safety Professionals. This information is derived from copyrighted materials that are owned by the Board of Certified Safety Professionals.*

Candidates are provided with an on-screen calculator during the exam. The on-screen calculator emulates the TI-30XS scientific calculator. Test centers do not provide physical calculators or allow candidates to bring in their own.

Make sure you know how to use the provided calculator, so you do not waste valuable time trying to understand how to use it once the examination clock starts. It is a good idea to practice working solutions and to be able to recall the correct calculator procedures.

Remember, solutions to computational items usually are rounded. You should select the answer closest to the computed value.

It is recommended that regardless of the calculator you use, you should spend a good deal of time practicing with it before taking the exam. This will help in saving valuable test-taking time and will also allow you to know the specific functions and capabilities of the calculator.

Summary

This chapter has been included to provide a basic review of math required to perform more complex equations throughout the course of this book. Hopefully, it has laid the groundwork for preparing you to move forward. If, however, you are having difficulty at this point, it may be wise to consider taking a more in-depth course in algebra and trigonometry at the local community college before attempting to take the examination. With a good understanding of the information provided in this chapter, you should be able to solve any of the equations or problems listed throughout the book, which will show how to work each and every equation listed on the CSP exam reference sheet.

6

Particulates and Gases

Every safety professional requires more than a basic understanding of particulates and gases, as they are a common hazard in today's work environment. In order to understand particulates and gases, you must have a good working knowledge of basic chemistry. Therefore, the chapter will begin by going through a basic review of chemistry. As in Chapter 5, this review is not intended to teach an entire semester course on chemistry, but rather, to serve as a general review.

Periodic Table of the Elements

The discussion of basic chemistry will start by reviewing the *periodic table of the elements.* The periodic table of the elements (or Periodic Table) displays all the known chemical elements in a tabular form. Currently, there are 118 individual elements listed on the periodic table. The key elements of the Periodic Table are shown in Figure 6.1.

An explanation of each of these terms is listed as follows:

Atomic Number

The *atomic number* is the number of protons found in the nucleus of an atom.

Atomic Mass

The *atomic mass* or weight of an atom includes protons, neutrons, and electrons. This weight is measured in grams. The atomic weight of any element is the average weight (of the natural isotopes) compared to carbon. The mass in grams of any element that is equal to that element's atomic weight is called one *gram-molecular weight*, or one *mole* (6.02×10^{23} atoms = Avogadro's number).

Note**:** When preparing for the Associate Safety Professional (ASP)/ Certified Safety Professional (CSP) examination, you must know the

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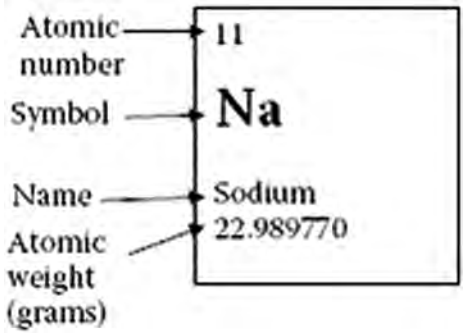


FIGURE 6.1
Element example (Source: Yates, W. David, 2024).

atomic weights of the more common elements. The more common elements and their atomic weights are as follows: sodium (Na) = 23, hydrogen (H) = 1, carbon (C) = 12, nitrogen (N) = 14, and oxygen (O) = 16. These common elements and their weights should be committed to memory.

Atoms

An atom is a basic unit of matter, which contains a nucleus. The *nucleus* contains positively charged *protons* and neutrally charged *neutrons.* Surrounding the nucleus is a cloud of negatively charged *electrons.* These electrons are bound to the nucleus by means of an electromagnetic force. The number of protons in an atom is always equal to the atomic number. The number of neutrons in an atom is equal to the atomic weight minus the atomic number. The number of electrons in an atom is dependent on the charge of the atom. For example, a neutrally charged atom has a number of electrons equal to the number of protons. For those atoms having a positive or negative charge, the number of electrons will change. In some cases, electrons are lost, which creates a charge to the atom. These charged atoms are referred to as *ions.* In the case of ions, you would subtract the charge from the atomic number. In the case of a positively charged ion, you would have fewer electrons than protons.

Electron shells are considered to be orbits around the nucleus. The number of electron shells present in an atom is determined by the number of electrons present. Each shell can contain a limited number of electrons. One way to think of shells is in terms of levels or distances away from the nucleus. These electron shells are labeled as 1, 2, 3, 4,... or k, 1, m, n, o. Table 6.1 is a list of shells (levels) and their maximum number of electrons in that shell:

For example, sodium (Na) has an atomic number of 11, as identified on the periodic table. It is a neutrally charged atom and therefore will also have 11 electrons. There will be 2 electrons in the first shell, 8 electrons in the second

TABLE 6.1
Shell Levels

Shell Level	Maximum No. of Electrons
1	2
2	8
3	16
4	32
5	64

Source: Yates, W. David (2024).

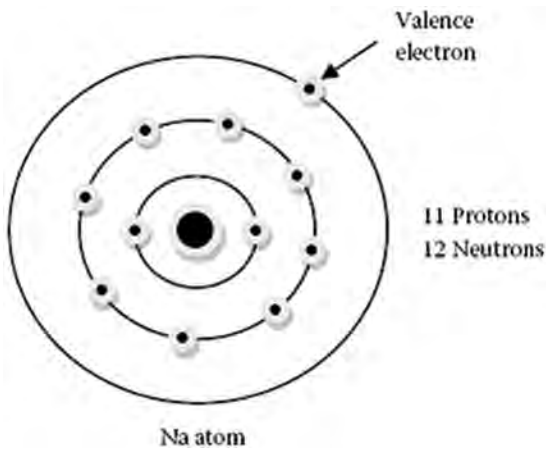


FIGURE 6.2
Sodium atom (Source: Yates, W. David, 2024).

shell, and 1 electron in the third (or outer) shell. The electrons in the outermost shell are referred to as *valence electrons*. Shells with a complete number of valence electrons are inert. Shells without a complete number or with one or two valence electrons tend to be more reactive. The illustration as provided in Figure 6.2 will show the various shells and their respective numbers:

Chemical Bonding

The two types of chemical bonding are ionic bonding and covalent bonding. *Ionic bonds* are formed when two atoms exchange electrons, as in the bonding of sodium (Na) and chlorine (Cl) to form table salt (NaCl). One electron from the sodium atom is lost to the chlorine atom, forming NaCl to stabilize the molecule, as illustrated in Figure 6.3.

Covalent bonds are those formed when electrons are shared between two atoms in a molecule, generally between atoms of the nonmetals. These atoms

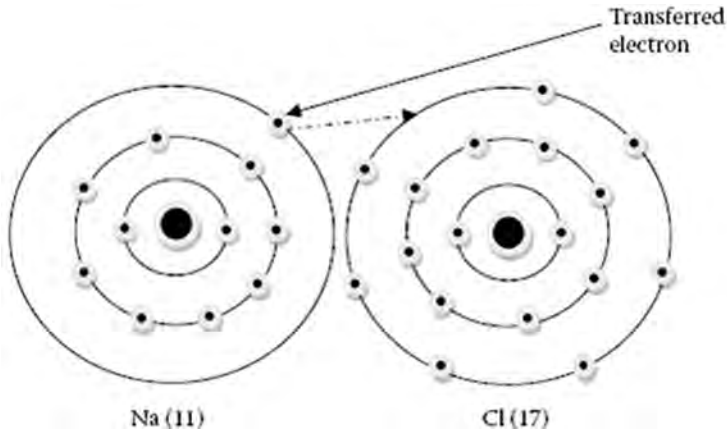


FIGURE 6.3
Ionic Bonding Example (Source: Yates, W. David, 2024).

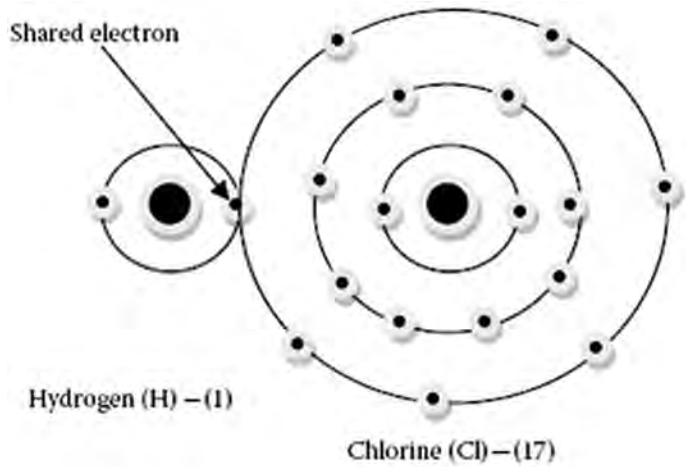


FIGURE 6.4
Covalent bonding example (Source: Yates, W. David, 2024).

gain electronic stability by sharing electrons so that they look like atoms of the noble gas nearest to them in atomic number. Covalent bonding is illustrated in Figure 6.4

Moles

As described above, a *mole* is an *SI* unit, which describes the atomic weight in terms of grams per mole. When we weigh 1 mol of a substance on a balance, this is called a *molar mass* and has the unit grams per mole. This idea is

critical as it will be used throughout this chapter and in the course of your professional career. An example of this is as follows:

NaCl or sodium chloride. Sodium has an atomic weight of 22.99 g and chlorine has an atomic weight of 35.453 g for a combined weight of 58.44 g, which is equivalent to 58.44 gram-molecular weight or 58.44 g/mol. Remember Avogadro's number is of 6.02×10^{23}. One mole of NaCl has 6.02×10^{23} atoms.

Molecules and Compounds

A *molecule* is a unit of matter formed by the chemical combination of two or more atoms, usually from different elements, but can be the same element. Chlorine (Cl) combines with hydrogen to form hydrochloric acid (or HC1). This is an example of atoms combining by chemical bonding to form a molecule. A *compound* is a substance composed of all the same kinds of molecules. For example, water is a compound composed entirely of water molecules (H_2O).

Mixtures

Compounds should not be confused with mixtures. Mixtures are not the result of chemical bonding; rather, they consist of separate elements or compounds that are mixed together. *Mixtures* include solutions, when a solute (e.g., sugar) is dissolved in a solvent (water). Like all mixtures, each component of a solution retains its own chemical properties.

Chemical Formulas

Chemical formulas are a shorthand way of expressing the composition of molecules and the way they react with one another. Hydrochloric acid, the chemical combination of hydrogen and chlorine, is abbreviated as HCl. This is the chemical formula for hydrochloric acid. In this case, there is one atom of hydrogen and one atom of chlorine in every molecule of HCl. If there is more than one identical atom in a molecule, the number is shown as a subscript after the symbol for that atom, as in the chemical formula for sulfuric acid (H_2SO_4). When writing a chemical formula, one should remember the "Law of Conservation," which states that matter can be neither created nor destroyed in a chemical reaction. Therefore, when writing chemical equations, the same number of atoms on one side of the equation must equal those on the opposite side of the equation. For example, in the case of carbon

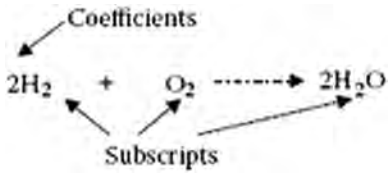


FIGURE 6.5
Chemical formula and equation example (Source: Yates, W. David, 2024).

dioxide, there is one carbon atom that combines with two oxygen atoms. This is illustrated as

$$\mathrm{C(carbon)} + \mathrm{O_2} = \mathrm{CO_2}.$$

Written as a chemical equation:

$$\mathrm{C} + \mathrm{O_2} \overset{\text{yields}}{\rightarrow} \mathrm{CO_2}.$$

You can see from the illustration above that there remain one carbon and two oxygen atoms on each side of the equation. The illustration as in Figure 6.5 shows the basic components of a chemical equation:

In this equation, the coefficients are multiplied by the subscript to give you a total. As you can see, there are four hydrogen atoms and two oxygen atoms on each side of the equation.

Note: When there is no subscript behind a symbol, it is assumed to be 1.

Atomic Weight of Compounds

To determine the atomic weight of compounds, one can simply add the atomic weight of the individual atoms, remembering to multiply the individual weights by the number of atoms of each present in the compound. For example, let's take hydrogen sulfate (H_2SO_4) and determine the atomic weight. As you can see, there are two hydrogen atoms, one sulfur atom, and four oxygen atoms in this compound. The individual weights are as follows: hydrogen (H), 1; sulfur (S), 32.066; and oxygen (O), 15.9994.

Hydrogen: 2 atoms × 1 (atomic weight)	= 2
Sulfur: 1 atom × 32.066 (atomic weight)	= 32.066
Oxygen: 4 atoms × 15.9994 (atomic weight)	= 63.9976
	98.0636 g

The total compound weight is 98.0636 g. Therefore, 1 mol of H_2SO_4 would be 98.0636 g.

Percentage of Element in a Compound (by Weight)

As a safety professional, you often have the need to determine the percentage of an element in a compound. To calculate the percentage of the element in a compound, we use the following method, as in the case of H_2SO_4:

We know that a mole of H_2SO_4 contains 98.0636 g. Let's determine the individual element percentage.

Hydrogen: 2 g/98.0636 g × 100	= 2.04%
Sulfur: 32.066 g/98.0636 g × 100	= 32.70%
Oxygen: 63.9976 g/98.0636 g × 100	= 65.26%
	100%

Acids, Bases, and pH's

In determining whether or not a solution is an acid or base, we must determine its *pH.* The pH is calculated as follows:

$$\mathrm{pH} = -\log\left|\mathrm{H}^{+}\right|$$

For example, you have a solution that contains 10^{-2} ions per liter. What is the pH of this solution?

$$\mathrm{pH} = -\log\left|10^{-2}\right|$$

$$\mathrm{pH} = -\log\left|0.01\right|$$

$$\mathrm{pH} = -\left(-2\right)$$

$$\mathrm{pH} = 2$$

The pH is a scalar measurement (0–14) that determines whether a chemical or solution is an acid, base, or neutral. A neutral solution is considered to be

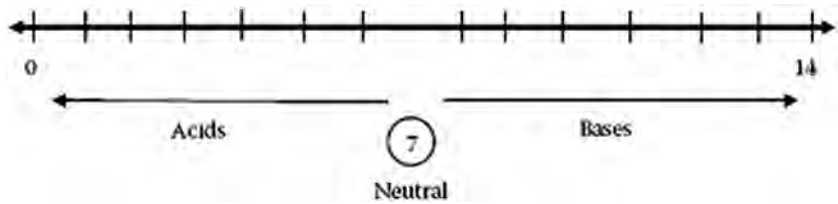


FIGURE 6.6
pH scale (Source: Yates, W. David, 2024).

7. Any pH below 7 is considered an acid, while a pH above 7 is considered a base. This is illustrated graphically in Figure 6.6

Gas Laws

There are four basic gas laws that need to be understood. They are Boyle's law, Charles' law, the ideal gas law, and the combined gas law.

Boyle's Law

Boyle's law states that at constant temperature, a fixed mass of gas occupies a volume that is inversely proportional to the pressure exerted upon it. Boyle's law written mathematically is

$$P_1V_1 = P_2V_2$$

where P = pressure exerted and V = volume of gas.

Example

A 3.7-L (liter) volume of gas exerts a pressure of 760 mm Hg. What would be the volume of the gas if the pressure decreased to 630 mm Hg?

$$(3.7\text{L})(760\text{ mm Hg}) = (630\text{ mm Hg})(V_2)$$

$$\frac{(3.7\text{L})(760\text{ mm Hg})}{630\text{ mm Hg}} = \frac{(630\text{ mm Hg})(V_2)}{630\text{ mm Hg}}$$

$$4.46\ L = V_2$$

As you can see, when the pressure is reduced, the volume increases, according to Boyle's law.

Charles' Law

Charles' law states that at constant pressure, the volume occupied by a fixed mass of gas is directly proportional to the absolute temperature. Written mathematically, Charles' law is shown below:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where V = volume of gas and T = temperature of gas (Kelvin temperature scale).

Example

A container contains a volume of 4.2 L of gas at a temperature of 32°C. What is the volume of gas if the temperature is increased to 37°C?

Remember that the temperature is measured in Kelvin; therefore, we must convert degrees Celsius to Kelvin. We do this as follows:

$$t_{\mathrm{K}} = t_{^\circ\mathrm{C}} + 273$$

where t_{K} = temperature in Kelvin and $t_{^\circ\mathrm{C}}$ = temperature in Celsius.

$$t_{\mathrm{K}} = 32^\circ\mathrm{C} + 273.$$

$$t_K = 305$$

The temperature 32°C is equal to 305 K, and the temperature 37°C is equal to 310 K.

We can now insert our known variables into the equation for Charles' law, as follows:

$$\frac{4.2\,\mathrm{L}}{305\,\mathrm{K}} = \frac{V_2}{310\,\mathrm{K}}$$

$$(310\,\mathrm{K})\frac{4.2\,\mathrm{L}}{310\,\mathrm{K}} = \frac{V_2}{310\,\mathrm{K}}(310\,\mathrm{K})$$

$$4.27\,\mathrm{L} = V_2$$

Ideal Gas Law

An ideal gas can be defined as a gas where all internal energy is in kinetic energy form and any change causes a change in temperature. The ideal gas law is written as follows:

$$PV = nRT$$

where

P = absolute pressure (total pressure exerted on a system [also written as psia]). Absolute pressure is equal to the gauge pressure plus the atmospheric pressure (unit of atmosphere or atm)

V = volume (liters)

T = temperature (Kelvin)

n = number of molecules (moles)

R = universal gas constant (8.3145 J/mol K)

Before we solve an example problem using the equation for the ideal gas law, it is first necessary to discuss some of the finer points of this equation. As you can see, these variables must be in specific units for the equation to be valid.

Conversion Factors for Converting Pressure Units to Atmospheric Pressure Units

To convert pressures to atmosphere pressures, use the following conversion factors:

1 atm = 14.6959488 pounds per square inch (psi)

1 atm = 29.9246899 inches of mercury (in Hg)

1 atm = 760 mm mercury (mm Hg)

1 atm = 760 torr (torr)

1 atm = 101,325 pascals (Pa)

1 atm = 101.325 kilopascals (kPa)

1 atm = 1.01325 bar (bar)

Conversion Factors for Converting Units of Volume to Liters

To convert units of volume to liters, use the following conversion factors:

1 L = 1000 milliliters (mL)

1 L = 1000 cubic centimeters (cm^3)

1 L = 1 cubic decimeter (dm^3)

1 L = 0.001 cubic meters (m^3)

1 L = 0.264172051 US gallons (gal)

1 L = 1.0566882 US quarts (qts)

Converting Grams to Moles

To convert from grams to moles, divide the number of grams by the molar mass (MM). For example, 1 mol of HCN is equal to 27 g. Three moles would

equal 81 g. Thus, to determine the number of moles of HCN, divide 81 g by 27 g to convert to 3 mol.

Example

What is the volume of 2 gram-mole of gas at an absolute pressure of 28.3 psia and a temperature of 42°C?

We must first convert the temperature to Kelvin. This is done as follows:

$$t_K = 42°C + 273 = 315K.$$

Now, insert the known data into the ideal gas law equation, as follows:

$$28.3\,\text{psia}(V) = 2\text{g} - \text{mol}(1.206)(315\text{K})$$

$$\frac{28.3\,\text{psia}(V)}{28.3\,\text{psia}} = \frac{759.78}{28.3\,\text{psia}}$$

$$V = 26.85.\text{L}$$

Note: 1 g-mol of ideal gas occupies 24.04 L (usually rounded to 24 L) or 0.02404 m^3.

Universal Gas Constant

The universal gas constant or *R* value in the ideal gas law is dependent upon the units used for pressure, temperature, volume, and number of moles. Table 6.2 is given to you on the Board of Certified Safety Professionals (BCSP) examination reference sheet.[1]

For example, using this chart provided on the BCSP examination reference sheet, if the volume (*V*) were in liters, temperature in Kelvin, moles in grams, and the pressure in psi, the universal gas constant or *R* value would be 1.206. Insert this value into your equation for the universal gas constant.

Combined Gas Law

The combined gas law combines both Charles' law and Boyle's law and is written mathematically as follows:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2},$$

where

P = absolute pressure (atm)
V = volume of gas (liters)
T = temperature of gas (Kelvin temperature scale)

TABLE 6.2

Value Gas Constant

Value Gas Constant							
			Absolute Pressure				
Volume	**Temperature**	**Moles**	**atm**	**psi**	**mm Hg**	**in Hg**	**ft. h_2o**
		g	0.00290	0.0426	2.20	0.00867	0.0982
ft^3	K	lb	1.31	19.31	999.0	39.3	44.6
	°R	g	0.00161	0.2366	1.22	0.0482	0.0546
		lb	0.730	10.73	555.0	21.8	24.8
		g	0.08205	1.206	62.4	2.45	2.78
L	K	lb	37.2	547.0	28,300.0	1113.0	1262.0
	°R	g	0.0456	0.670	34.6	1.36	1.55
		lb	20.7	304.0	15,700.0	619.0	701.0

Example

A gas has a volume of 3.9 L, a pressure of 1.3 atm, and a temperature of 295 K. If the pressure remains constant, but the gas is heated to 308 K, what is the new volume of the gas?

$$\frac{1.3\,\text{atm}(3.9\text{L})}{295\text{K}} = \frac{1.3\,\text{atm}(V_2)}{308\text{K}}$$

$$\frac{308\text{K}(1.3\,\text{atm})(3.9\text{L})}{295\text{K}} = \frac{(1.3\,\text{atm})(V_2)308\text{K}}{308\text{K}}$$

$$\frac{1561.56\,\text{atm}-\text{L}}{295\text{K}(1.3\,\text{atm})} = \frac{1.3\,\text{atm}(V_2)}{1.3\,\text{atm}}$$

$$4.1\text{L} = V_2$$

Concentrations of Vapors, Gases, and Particulates

As a way of introduction into this section, I would first like to provide some definitions that you will find helpful in understanding this section.

Vapors: A gaseous form of a substance that is normally a solid or liquid at room temperature.

Gases: Substances that completely occupy a space and can be converted to a liquid or solid by increasing or decreasing temperature.

Vapor pressure: The pressure that a vapor at equilibrium with a pure liquid at a given temperature exerts to the surrounding atmosphere.

Particulate: Fine solid or liquid particles, such as dust, fog, mist, smoke, or spray.

Dust: Solid particles generated by mechanical action (crushing, grinding, etc.). Size ranges are usually from 0.1 to 30 μm.

Fume: Airborne solid particles formed by condensation of vapor (i.e., welding fumes). Size ranges from 0.001 to 1.0 μm.

Mist: Suspended liquid droplets generated by condensation or atomization (fogs are formed by condensation). Size ranges from 0.01 to 10 μm.

Fibers: Particulate with an aspect ratio (length to width) of 3:1.

Standard Temperature and Pressure

Throughout your professional career and specifically on the ASP/CSP exam, you encounter the term *STP* (*Standard Temperature and Pressure*). It is critical that you understand its meaning, as it will drastically change the outcome of your calculations, if performed incorrectly. For the purposes of discussing concentrations of gases and vapors, STP is the standard temperature and pressure of 25°C and 1 atm. This standard is provided on the BCSP examination reference sheet. When discussing physical sciences, STP is equal to 0°C and 1 atm, and when discussing ventilation, STP is equal to 70°F and 1 atm. These last two are also listed on the BCSP examination reference sheet.

Standards and Regulations

There are two standards that we need to reference before proceeding. The first standard is the *Permissible Exposure Limit* or *PEL*, which is established by the US Occupational Safety and Health Administration (OSHA), for each contaminant regulated. The PEL establishes the maximum exposure concentration to a contaminant that an employee can be exposed to in an 8-h workday. The OSHA PEL is the only standard that is enforceable by law. The second standard to be discussed is the *Threshold Limit Value* or *TLV*, which is established by the American Conference of Governmental Industrial Hygienist (ACGIH). The TLV establishes the exposure time for various contaminants in an 8-h workday. The majority of contaminants having a TLV are consistent with the requirements of the PEL. However, for some contaminants listed, the exposure concentrations are more stringent than the PEL. This is primarily attributed to the fact that ACGIH does not consider the economic impact in establishing the standard. The TLV is not enforceable under the law. When faced with a conflict in the standards, it is strongly recommended that the safety professional adhere to the more stringent standard. This is in keeping with the philosophy of holding the safety and health of the employee paramount in any decision.

Time-Weighted Average

A *time-weighted average* or *TWA* is the concentration that an employee is exposed to for a specified period. The PEL and TLV are both established for a

TWA of 8 h. The average person should have no adverse health effects to the exposure at these concentrations. The TWA is based on, or rather, compared to the OSHA PEL or the ACGIH TLV. Each contaminant has its own unique PEL and can be found in 29 CFR 1910.1000 (Table Z-l). The TLV can be found on the material safety data sheet (MSDS) or various other sources.

To calculate a TWA, we use the following equation:

$$TWA = \frac{(C_1T_1)+(C_2T_2)+\cdots(C_nT_n)}{\text{total hours workes}}$$

where C = concentration (ppm or mg/m^3) and T = time of exposure (minutes or hours).

Example

An employee is exposed to carbon dioxide (CO_2) concentrations of 5300 ppm for 2 h, 3500 ppm for 3 h, and 5125 ppm for 3 h. What is the TWA?

$$\text{TWA} = \frac{(5200\,\text{ppm})(2\,\text{h})+(3500\,\text{ppm})(3\,\text{h})+(5125\,\text{ppm})(3\,\text{h})}{8\,\text{h}}$$

$$\text{TWA} = \frac{(10,600\,\text{ppm})+(10,500\,\text{ppm})+(15,375\,\text{ppm})}{8\,\text{h}}$$

$$\text{TWA} = \frac{36,475\,\text{ppm}}{8\,\text{h}}$$

$$\text{TWA} = 4559.38\,\text{ppm}$$

On the basis of this calculation, the employee was exposed to a TWA concentration of 4559.38 ppm in an 8-h period. Now we look in Table Z-l to obtain the PEL for CO_2, which is 5000 ppm. Therefore, 4559.38 ppm is less than the PEL. This employee has not exceeded the standard.

Calculating PELs/TLVs for Periods Greater than 8 h

Many places of employment do not work a standard 8-h workday. Sometimes they work a 10- or 12-h work shift. How does an 8-h PEL/TLV compare to a 12-h shift concentration? To calculate a PEL/TLV for a period greater than 8 h, you would use the following equation:

$$\text{PEL}_{n\,\text{hours}} = \frac{\text{PEL}(\text{or TLV})\times 8\,\text{h}}{(\text{actual shift worked in hours})}$$

Example

OSHA has established a PEL of 5.0 mg/m^3 for respirable dust. What would be the modified PEL for an employee working a 12-h shift?

$$\text{PEL}_{12\,\text{hours}} = \frac{5.0\frac{\text{mg}}{\text{m}^3} \times 8\,\text{h}}{12\,\text{h}}$$

$$\text{PEL}_{12\,\text{hours}} = \frac{40\text{mg}/\text{m}^3}{12\,\text{h}}$$

$$\text{PEL}_{12\,\text{hours}} = 3.33\text{mg}/\text{m}^3$$

The established 12-h PEL for respirable dust would be 3.33 mg/m^3.

Gaseous Mixtures

Mixtures are simply the mixing of two or more chemicals. Sometimes, employees are exposed to several contaminants at the same time. How do we determine if the employee has been overexposed? To determine exposure for gaseous mixtures, we use the following equation:

$$\text{TVL}\left(\text{or PEL}\right)_{m-\text{gaseous}} = \frac{C_1}{\text{TLV}_1} + \frac{C_2}{\text{TLV}_2} + \cdots \frac{C_n}{\text{TLV}_n}$$

If the result for this equation is greater than 1, then the mixture TLV (gaseous) has been exceeded.

Example

Given the following information, determine whether an employee's exposure to a gaseous mixture has been exceeded. Chemical A has a TLV of 200 ppm and a measured concentration of 150 ppm; Chemical B has a TLV of 300 ppm and a measured concentration of 100 ppm; and Chemical C has a TLV of 500 ppm and a measured concentration of 100 ppm.

$$\text{TLV}_{\text{m-gaseous}} = \frac{150\,\text{ppm}}{200\,\text{ppm}} + \frac{100\,\text{ppm}}{300\,\text{ppm}} + \frac{100\,\text{ppm}}{500\,\text{ppm}}$$

$$\text{TLV}_{\text{m-gaseous}} = 0.75\,\text{ppm} + 0.333\,\text{ppm} + 0.2\,\text{ppm}$$

$$\text{TLV}_{\text{m-gaseous}} = 1.28\,\text{ppm}$$

The result is 1.28, which is greater than 1; therefore, this employee was overexposed to the gaseous mixture.

Liquid Mixtures

Just as in gaseous mixtures, it is necessary for the safety professional to determine an employee's exposure to liquid mixtures. To do this, we use the following equation:

$$\mathrm{TLV}_{\mathrm{m-liquid}} = \frac{1}{\left(\frac{f_1}{\mathrm{TLV}_1} + \frac{f_2}{\mathrm{TLV}_2} + \cdots \frac{f_n}{\mathrm{TLV}_n}\right)}$$

where f = fraction of chemical (weight percent of liquid mixture) and TLV = threshold limit value of the chemical.

Example

A liquid mixture contains 40% (by weight) heptanes, 20% methyl chloroform, and the balance is perchloroethylene. Assuming that all of this liquid evaporates and that atmospheric composition is similar to the original liquid, calculate the TLV exposure for the gaseous mixture generated from this liquid mixture. The TLVs are as follows: heptane = 1600 mg/m^3, methyl chloroform = 1900 mg/m^3, and perchloroethylene = 335 mg/m^3.

$$\mathrm{TLV}_{m-\mathrm{liquid}} = \frac{1}{\frac{0.4}{1600\mathrm{mg/m^3}} + \frac{0.2}{1900\mathrm{mg/m^3}} + \frac{0.4}{335\mathrm{mg/m^3}}}$$

$$\mathrm{TLV}_{\mathrm{m-liquid}} = \frac{1}{0.0015\mathrm{mg/m^3}}$$

$$\mathrm{TLV}_{\mathrm{m-liquid}} = 645.46\mathrm{mg/m^3}$$

645.46 mg/m^3 is the TLV or PEL for this liquid mixture. This is the maximum concentration that an employee can be exposed to for this liquid mixture in an 8-h period.

Percentage of TLV Mixture

To determine the percentage of the TLV/PEL, use the following equation:

$$\%\mathrm{TLV}_{\mathrm{mixture}} = \left(\frac{f_1}{\mathrm{TLV}_1} + \frac{f_2}{\mathrm{TLV}_2} + \cdots \frac{f_n}{\mathrm{TLV}_n}\right)$$

where f = measured concentration of contaminant and TLV = established TLV of contaminant.

Example

An employee is exposed to 425 mg/m^3 of heptane, 270 mg/m^3 of methyl chloroform, and 175 mg/m^3 of perchloroethylene. What is the percentage of the TLV that the employee has been exposed to for this mixture, using 645.46 mg/m^3 as the TLV?

$$\%\text{TLV}_{\text{mixture}} = \left(\frac{425\text{mg/m}^3}{1600\text{mg/m}^3} + \frac{270\text{mg/m}^3}{1900\text{mg/m}^3} + \frac{175\text{mg/m}^3}{335\text{mg/m}^3} \right) 100$$

$$\%\text{TLV}_{\text{mixture}} = (0.27 + 0.14 + 0.52)100$$

$$\%\text{TLV}_{\text{mixture}} = 93\%$$

This employee has been exposed to 93% of the established TLV for this mixture or approximately 600.28 mg/m^3.

Converting mg/m^3 to ppm

To convert mg/m^3 to ppm, use the following equation:

$$\text{ppm} = \frac{\text{mg/m}^3 \times 24.42}{\text{MW}}$$

where
ppm = parts per million
mg/m^3 = measured mg/m^3 of the contaminant
MW = molecular weight of contaminant
24.42 = constant = 1 g-mol

Example

Convert 22 mg/m^3 of H_2S (hydrogen sulfide) to ppm. The MW of hydrogen (H) is 1 and the MW of sulfur (S) is 32.

Converting ppm to mg/m^3

To convert from ppm to mg/m^3, use the following equation:

$$\text{mg/m}^3 = \frac{(\text{ppm})(\text{MW})}{24.45}$$

where
ppm = parts per million
mg/m^3 = measured mg/m^3 of the contaminant
MW = molecular weight of contaminant
24.45 = constant = 1 g-mol

Example

Convert 16.3 ppm of hydrogen sulfide to mg/m^3. MW: H = 1; S = 32.

$$\text{mg/m}^3 = \frac{(16.3\,\text{ppm})(33\,\text{g/mol})}{14.45\,\text{g/mol}}$$

$$\text{mg/m}^3 = \frac{537.9\,\text{ppm}}{24.45}$$

$$\text{mg/m}^3 = 22$$

Lower Flammability Limit of Mixtures

The flammability range for any chemical is the range of concentrations that exist between the lower flammability limit (LFL) and the upper flammability limit (UFL). The range varies from chemical to chemical. This information can be conveniently located on the material safety data sheet (MSDS) or other sources. For example, if an individual chemical has an LFL of 1.7% to 8.1%, ignition only occurs if the concentration is between this range. To calculate the LFL of a mixture, use the following equation:

$$\text{LFL}_{\text{mixture}} = \frac{1}{\left(\frac{f_1}{\text{LFL}_1} + \frac{f_2}{\text{LFL}_2}\frac{f_n}{\text{LFL}_n}\right)}$$

where f = fraction of chemical in the mixture and LFL = lower flammability limit.

Example

A liquid mixture contains 40% heptanes, 20% methyl chloroform, and the balance is perchloroethylene. What is the LFL of the mixture? LFLs: heptane = 1.2%, methyl chloroform = 1.7%, and perchloroethylene = 1.1%.

$$\mathrm{LFL}_{\mathrm{mixture}} = \frac{1}{\left(\frac{0.4}{1.2} + \frac{0.2}{1.7} + \frac{0.4}{1.1}\right)}$$

$$\mathrm{LFL}_{\mathrm{mixture}} = \frac{1}{(0.333 + 0.118 + 0.364)}$$

$$\mathrm{LFL}_{\mathrm{mixture}} = \frac{1}{0.815}$$

$$\mathrm{LFL}_{\mathrm{mixture}} = 1.23\%$$

Referenced Equations

Boyle's Law

$$P_1V_1 = P_2V_2$$

where P = pressure exerted and V = volume of gas.

Charles' Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where V = volume of gas and T = temperature of gas (Kelvin temperature scale).

Ideal Gas Law

$$PV = nRT$$

where

P = absolute pressure (total pressure exerted on a system [also written as psia]). Absolute pressure is equal to the gauge pressure plus the atmospheric pressure (unit of atmosphere or atm)

V = volume (liters)

T = temperature (Kelvin)

n = number of molecules (moles)

R = universal gas constant (8.3145 J/mol K)

Combined Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

where
P = absolute pressure (atm)
V = volume of gas (liters)
T = temperature of gas (Kelvin temperature scale)

Time-Weighted Average

$$TWA = \frac{(C_1T_1) + (C_2T_2) + \cdots (C_nT_n)}{\text{total hours worked}}$$

where C = concentration (ppm or mg/m^3) and T = time of exposure (minutes or hours).

Calculating PEL's/TLVs for Periods Greater than 8 Hours

Gaseous Mixtures

$$\text{TLV(or PEL)}_{\text{m-gaseous}} = \frac{C_1}{\text{TLV}_1} + \frac{C_2}{\text{TLV}_2} + \cdots \frac{C_n}{\text{TLV}_n}$$

Liquid Mixtures

$$\text{TLV}_{\text{m-liquid}} = \frac{1}{\left(\frac{f_1}{\text{TLV}_1} + \frac{f_2}{\text{TLV}_2} + \cdots \frac{f_n}{\text{TLV}_n}\right)}$$

where f = fraction of chemical (weight percent of liquid mixture) and TLV = threshold limit value of the chemical.

Percentage of TLV for Mixtures

$$\%\text{TLV}_{\text{mixture}} = \left(\frac{f_1}{\text{TLV}_1} + \frac{f_2}{\text{TLV}_2} + \cdots \frac{f_n}{\text{TLV}_n}\right)$$

where f = fraction of chemical (weight percent of liquid mixture) and TLV = threshold limit value of the chemical.

Calculating PEL/TLV for Silica

$$\text{PEL}_{\text{silica}} = \frac{10\text{mg/m}^3}{\%\text{SiO}_2 + 2}$$

where $\%\text{SiO}_2$ = the percentage of silica in the batch.

Converting mg/m³ to ppm

$$\text{ppm} = \frac{\text{mg/m}^3 \times 24.45}{\text{MW}}$$

where
ppm = parts per million
mg/m³ = measured mg/m³ of the contaminant
MW = molecular weight of contaminant
24.45 = constant = 1 g-mol

Converting ppm to mg/m³

To convert from ppm to mg/m³, use the following equation:

$$\text{mg/m}^3 = \frac{(\text{ppm})(\text{MW})}{24.45}$$

where
ppm = parts per million
mg/m³ = measured mg/m³ of the contaminant
MW = molecular weight of contaminant
24.45 = constant = 1 g-mol

LFLs of Mixtures

$$\text{LFL}_{\text{mixture}} = \frac{1}{\left(\frac{f_1}{\text{LFL}_1} + \frac{f_2}{\text{LFL}_2} + \cdots \frac{f_n}{\text{LFL}_n}\right)}$$

where f = fraction of chemical in the mixture and LFL = lower flammability limit.

Key Information to Remember on Particulates and Gases

1. The atomic number is the number of protons in a nucleus.
2. The atomic mass or weight of an atom includes protons, neutrons, and electrons.
3. Avogadro's number is 6.02×10^{23} atoms.
4. One mole is equal to 6.02×10^{23} atoms.
5. Atomic weights of the common elements are as follows: sodium (Na) = 23, hydrogen (H) = 1, carbon (C) = 12, nitrogen (N) = 14, oxygen (O) = 16, and sulfur (S) = 32.
6. Valence electrons are those electrons in the outer shell of an atom. A complete number in a shell creates a more stabilized atom.
7. Ionic bonding is the transfer of an electron from one atom to another.
8. Covalent bonding is the sharing of electrons between two atoms.
9. The law of conservation should be kept in mind when writing chemical formulas. Energy or mass cannot be created or destroyed, but it can change its form.
10. The universal gas constant value is dependent upon the units of pressure, volume, temperature, and moles.
11. In industrial hygiene equations, the STP is equal to 25°C and 1 atm.
12. Ventilation STP is equal to 70°F and 1 atm.
13. Air density STP = 0.075 lb/ft^3 at 70°F and 1 atm.
14. Physical science STP = 0°C and 1 atm.

Reference

1. Board of Certified Safety Professionals, *Examination Reference Sheet, Gas Constant Value.* (*Note: This reference is no longer available on the BCSP website, but the individual equations are embedded within the examinations.*)

7

Toxicology

Toxicology is the study of the adverse effects of chemicals on living organisms. It is critical for the practicing safety professional, at all levels, to have a solid understanding of basic toxicology. Hemlock, opium and toxic metals, such as antimony, copper and lead were described as early as 1500 B.C. The Greek physician, Dioscorides, (circa A.D. 50–90), attempted to classify poisons into three categories, plant poison, animal poison, and mineral poisons. In the 15th century, physicians recognized that certain occupations were exposed to toxic substances. Workers involved in goldsmithing, mining, printing and pottery making were exposed to lead and mercury, which was documented in "On the Miner's Sickness and Other Dieases of Miners" (Paracelsus, 1567) and "Discourse on the Diseases of Workers", (Ramazzini, 1700). Paracelsus is often referred to as the father of toxicology.

Since the days of Paracelsus and Ramazzini, great advances have taken place in the field of Toxicology. The saying, "The Dose Makes The Poison", is very true. Everything can be poisonous to humans and animals, given enough dosage. For example, water is a requirement for humans to survive. However, if someone were to drink enough water, it could result in water intoxication or death. This chapter will cover the basics of toxicology, the major diseases and associated toxins.

Definitions

Before getting into the chapter and our review of toxicology, it is necessary to have a basic understanding of the terms and definitions.

Toxicology: The science dealing with the study of poisons and their effects.

Toxicity: The degree to which a substance can harm an exposed organism.

Hazard: The potential for a substance to cause harm (toxicity plus exposure).

Risk: The quantitative measurement or estimate of a hazard.

Poison: A substance that is harmful to an organism.

Xenobiotic: It is a substance which is found in an organism, but is not normally produced or expected to be present in it.

Dose–response theory: Increasing the dose increases the effect.

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Tolerance: Ability to withstand exposure.

Chronic exposure: Long-term exposure (days, weeks, months, and years).

Acute exposure: Short-term exposure (minutes, hours, and days).

NOEL: No observed effect level.

NOAEL: No observed adverse effect level.

LOEL: Lowest observed effect level.

LOAEL: Lowest observed adverse effect level.

Latency period: The period between exposure and the onset of symptoms.

LD_{50}: Lethal dose. It is the amount of material (normally liquid or solid) that kills 50% of the laboratory animals.

LC_{50}: Lethal concentration. It is the amount of material (normally airborne concentrations) that kills 50% of laboratory animals.

IDLH: Immediately Dangerous to Life and Health

Routes of Entry

When discussing poisons and toxins and their effects on humans or animals, one of the first things to consider is their method of entry into the body. In this section, we will discuss inhalation, ingestion, absorption, percutaneous, and intravenous routes of entry.

Inhalation

Entry through inhalation is obviously respiratory in nature. Therefore, it is necessary to review the basics of the respiratory system in terms of its anatomy and physiology. The respiratory system consists of the nose, nasal passages, mouth, epiglottis, pharynx, larynx, trachea, bronchi, and alveoli. Air enters the body through the nose or mouth and travels through to the alveoli (see Figure 7.1). The body's natural defense against foreign bodies include mucus in the linings of the nose and sinus cavities and cilia in the nose. Particles can be trapped and expelled through coughing by the mucus. Furthermore, particles can also be captured by the cilia. Once the air (and the gaseous makeup of air) enters the alveoli (air sacs), which lie near blood vessels, the molecules of air enter the bloodstream through permeation. Oxygen enters the bloodstream, and carbon dioxide is expelled through the respiratory system as outgoing air. This process is known as *respiration*. In a normal relaxed state, humans breathe in and out 10–14 times per minute, with each breath lasting 4–6 s. In a minute, 4.3–5.7 liters of air are breathed in. As a person's activity increases, so does their respiratory rate, which can be up to one breath per second, with a total intake of up to 120 liters.[1] This volume is referred to as the *Tidal Volume* (Figure 7.1).

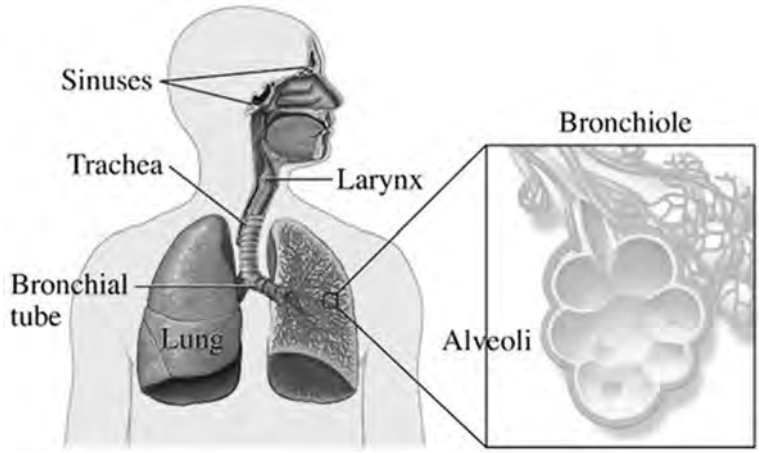


FIGURE 7.1
Diagram of respiratory system (Nucleus[2]). (Illustration Copyright © 2009 Nucleus Medical Art. All rights reserved. www.nucleusinc.com).

Ingestion

Ingestion of toxic or other substances is through the mouth. When swallowing a substance, the substance enters the digestive system and ultimately into the bloodstream through the stomach or intestinal tract. A chemical does not normally enter through this route as quickly as in inhalation. However, through this route, the substance can travel throughout the system, just as in other routes of entry.

Absorption

A substance can be absorbed through the skin and enter the bloodstream and travel throughout the body. The skin acts as a natural barrier against foreign substances. A foreign substance will enter the bloodstream through the skin more rapidly when the skin has lacerations or abrasions.

Percutaneous and Intravenous Injections

Percutaneous and intravenous injections are primarily medical procedures that intentionally invade the skin to administer a regulated dose of medicine. However, on occasion, an accidental injection, such as a needle-stick, may occur.

Dose–Response Relationship

The *dose–response relationship*, or *exposure–response relationship*, describes the change in effect on an organism caused by differing levels of exposure (or

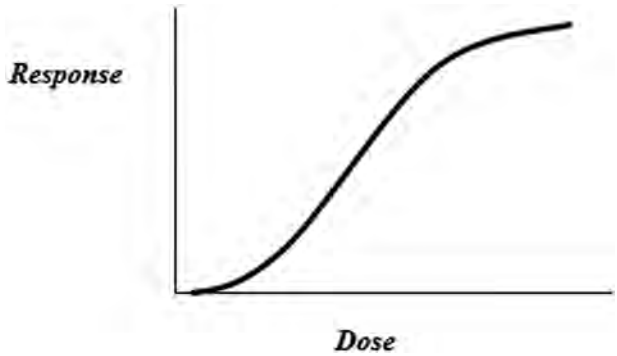


FIGURE 7.2
Dose–response curve (Source: Yates, W. David 2024).

doses) to a stressor (usually a chemical) after a certain exposure time (see Figure 7.2).

In other words, the higher the dose, the greater the response. A lethal dose (50%) is demonstrated in Figure 7.3: lethal dose (50%).

Exposures to Chemical Combinations

Any number of combinations of chemicals is possible in today's work environments. Various chemicals react differently with other chemicals and have varying effects on humans and animals in these varying combinations. These effects can be described as additive, antagonistic, synergistic, or potentiating. Each of these is described below.

Additive: The combined effect of the chemicals is equal to the sum of each chemical acting independently. To use a mathematical example, 2 + 2 = 4.

Antagonistic: When combined, the two chemicals interfere with each other. Example: 3 + (–2) = 1.

Synergistic: The combined effect of two chemicals is much greater than the sum of the effect of each agent acting independently. Example: 2 + 2 = 10.

Potentiating: One substance does not have a toxic effect on a certain organ system; however, when it combines with another chemical, it makes the combination of the two greater. An example is 2 + 0 = 10.

Other classifications of chemicals or toxins include carcinogens, co-carcinogens, epigenetics, genotoxins, mutagens, clastogens, and teratogen, which are described below.

Carcinogen: Any substance or agent known to cause cancer. Carcinogens do not adhere to the dose–response curve.

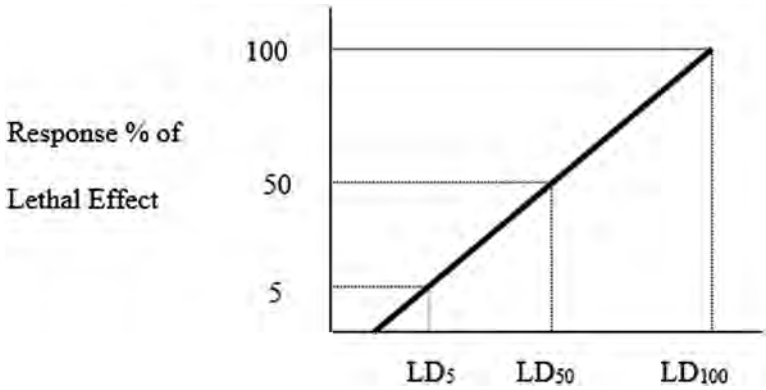


Figure 7.3
Graphic representation of lethal dose/concentration (Source: Yates, W. David 2024).

Co-carcinogen: These agents, when applied immediately prior to or with a genotoxic carcinogen, enhance the oncogenic (cancerous) effect of the agent.

Epigenetic: Changes in phenotype (appearance) or gene expression caused by mechanisms other than changes in the underlying DNA sequence.

Genotoxic: These materials are known to be potentially mutagenic and carcinogenic in nature. They act directly by altering the DNA.

Mutagen: A physical or chemical agent that changes the genetic material (usually DNA) of an organism and thus increases the frequency of mutations above the natural background level.

Teratogens: Any agent that can disturb the development of an embryo or fetus.

Stages of Cancer

There are four stages of cancer. They are as follows:

- Initiation
- Latency period
- Promotion
- Progression

Initiation

Initiation can be described as the first step in cancer development. Initiators, if not already reactive with DNA, become altered via drug-metabolizing enzymes in the body, which makes them available to cause changes in the

DNA, or mutations. These initiators are often specific to particular tissue types or species. The effects of initiators are irreversible until its death. Any daughter cell reproduced from an initiator also carries mutations.

Latency Period

As with any chemical, the latency period can be described as the time period from exposure to the onset of symptoms. In cancer development, the latency period is the time period where the mutations lie dormant.

Promotion

Once a mutation occurs as a result of the initiator, it is susceptible to the effects of promoters. These compounds promote the proliferation of the cell, giving rise to a large number of daughter cells containing the mutation created by the initiator.

Progression

The term progression refers to the transformation of a benign tumor into a neoplasm and to malignancy.

Types of Poisons

Poisons can be described as hepatotoxins, nephrotoxins, or neurotoxin. *Hepatoxins* are those chemicals or agents having an adverse effect on the liver or blood. *Nephrotoxins* are those chemicals or agents having an adverse effect on the kidneys, and *neurotoxins* are those agents having an adverse effect on the nervous system.

Ames Testing

Ames testing is a procedure to determine whether or not a chemical is a mutagen. There is a high correlation between the mutagenic trait of a chemical and its ability to cause cancer. The bacterium used in the test is a strain of *Salmonella typhimurium* that carries a defective (mutant) gene, making it unable to synthesize the amino acid histidine (His) from the ingredients in its culture medium.

Cohort Study

A cohort study is a study in which subjects who presently have a certain condition and/or receive a particular treatment are followed over time and compared with another group who are not affected by the condition under investigation. For research purposes, a cohort is any group of individuals who are linked in some way or who have experienced the same significant life event within a given period.

Advantages

One of the advantages of cohort analysis is that the study design does not require strict random assignment of subjects, which is, in many cases, unethical or improbable.

Disadvantages

One of the most difficult tasks in cohort studies is to assess whether associations between cohort and dependent variables derived from the studies are of a causal nature or not. Cohort studies are subject to the influence of factors over which the investigators most often do not have full control, and the findings from these studies are more open to threats to validity than those of studies with an experimental research design.

Case–Control Study

A study that compares two groups of people: those with the disease or condition under study and a very similar group of people who do not have the disease or condition (controls). Researchers study the medical and lifestyle histories of the people in each group to learn what factors may be associated with the disease or condition.

Cross-Sectional Study

Cross-sectional studies form a class of research methods that involve observation of some subset of a population of items all at the same time, in which groups can be compared at different ages with respect to independent variables, such as IQ and memory.

Common Occupational Diseases and Disorders Caused by a Contributing Agent or Substance

An *occupational disease* refers to those illnesses caused by exposures in the workplace. The list of diseases or illnesses that follow is common in today's work environments. The list is not all-inclusive but is provided as a review and is likely to be seen on the ASP/CSP examinations.

Asbestosis and Asbestos-Related Illnesses

Asbestos is a naturally occurring mineral used for high-temperature areas, decorative treatments, and binding of materials. The inhalation of the fibers can result in asbestosis, cancer, and mesothelioma.[3]

Asbestosis is a respiratory disease caused by the inhalation of asbestos fibers. The fibers, when inhaled, reach the alveoli, where they create a "scarring" of the lung tissue. As you recall in the respiratory system review section of this chapter, the alveoli are where gas exchanges between the respiratory and circulatory systems are made. The alveoli become scarred and prohibit the normal exchange of oxygen and carbon dioxide. The severity of the disease depends entirely on how long the person was exposed to asbestos and in what concentrations. There is a strong correlation between asbestos exposure and smoking for the development of lung cancer. There are no known cures for asbestosis. However, stopping exposure to asbestos may slow or stop the progression. The latency period for asbestosis is 10–20 years. The latency period for asbestos-related cancer is 20–30 years. *Mesothelioma* is an asbestos-related cancer of the lining of the lung (pleura) or the lining of the abdominal cavity (peritoneum). Mesothelioma is a very rare form of cancer. Mesothelioma is incurable, but several treatments are available including surgery, chemotherapy, and radiation.

The OSHA PEL for asbestos is 0.1 fibers/cubic centimeter. The method of sampling for asbestos uses a 0.8-µm mixed-cellulose ester filter (MCEF) and phase contrast microscopy (PCM). When testing for airborne concentrations in schools (K5-Grade 12), the Asbestos Hazard Emergency Response Act (AHERA) applies and requires that clearance monitoring be performed using 0.45-µm MCEF cassettes, with a 2-in. cowl and transmission electron microscopy (TEM). The OSHA standard for asbestos is 29 CFR 1910.1001.

Brucellosis

Brucellosis, is also called Bang's disease, Gibraltar fever, Malta fever, Maltese fever, Mediterranean fever, rock fever, or undulant fever, is a highly contagious zoonosis caused by the ingestion of unsterilized milk or meat from infected animals, or close contact with their secretions. Most cases are caused by occupational exposure to infected animals or the ingestion of unpasteurized dairy products. The latency period for Brucellosis is 3–60 days.[4]

Benzene-Related Illnesses

Benzene is an aromatic hydrocarbon that is produced by the burning of natural products. It is a component of products derived from coal and petroleum and is found in gasoline and other fuels. Benzene is used in the manufacture of plastics, detergents, pesticides, and other chemicals. Research has shown benzene to be a carcinogen (cancer-causing). With exposures from less than 5 years to more than 30 years, individuals have developed and died from leukemia. Long-term exposure may affect bone marrow and blood production. Long-term exposure to high levels of benzene in the air can cause leukemia, particularly acute myelogenous leukemia. Benzene has been determined by the U.S. Department of Health and Human Services to be a known carcinogen. Short-term exposure to high levels of benzene can cause drowsiness, dizziness, unconsciousness, and death. [5]

The OSHA 8-h PEL is 10 ppm, with a ceiling limit of 25 ppm for a 10-min period. The maximum peak concentration for an 8-h shift is 50 ppm. The OSHA standard for benzene is 29 CFR 1910.1028.

Byssinosis

Byssinosis is a disease of the lungs caused by breathing in cotton dust or dust from other vegetable fibers such as flax, hemp, or sisal while at work. Byssinosis is most common in people who work in the textile industry. Those who are sensitive to the dust can develop an asthma-like condition after being exposed. In those with asthma, being exposed to the dust makes breathing more difficult, but in byssinosis, the symptoms usually go away by the end of the workweek. After long periods of exposure, symptoms can continue throughout the week without improving.

Methods of prevention in the United States have reduced the number of cases, but byssinosis is still common in developing countries. Smoking increases the risk for this disease. Being exposed to the dust many times can lead to chronic lung disease and shortness of breath or wheezing.[6]

The OSHA PEL for cotton dust exposure is 1.0 mg/m^3. The OSHA standard is 29 CFR 1910.1043.

Arsenic-Related Illnesses

Chronic exposure to arsenic in the occupational setting, skin lesions, and peripheral neuropathy are the most common adverse effects. Patchy hyperpigmentation is the classic skin lesion of chronic arsenic exposure. Other adverse effects include anemia, leukopenia, thrombocytopenia, eosinophilia, and liver injury. Arsenic exposure occurs when workers sand or burn this wood. Arsenic is used as an alloy in lead-acid batteries. Inorganic arsenic is no longer used in agriculture in the USA. Organic arsenic pesticides (cacodylic acid, disodium methylarsenate, and monosodium methylarsenate) are

used on cotton.NIH[7] The high-risk occupations at greatest risk of arsenic poisoning include the following:

- Applying arsenic preservatives to wood
- Manufacturing of pesticides containing arsenic
- Sawing or sanding arsenic-treated wood
- Smelting or casting lead
- Smelting or refining of zinc or copper

The current OSHA PEL for arsenic is 10 μg/m^3 (8-h TWA). The NIOSH (National Institute for Occupational Safety and Health) 15-min limit for arsenic (airborne concentration) is 2 μg/m^3.

Berylliosis and Beryllium-Related Illnesses

Berylliosis is a lung disease resulting from the inhalation of beryllium. All compounds of beryllium should be considered potentially harmful if inhaled, even in minute quantities. The current OSHA PEL for beryllium exposure is 2.0 μg/m^3, 8-h TWA. It has a ceiling limit of 5 μg/m^3 not to be exceeded for more than 30 min and a never-to-exceed limit of 25 μg/m^3. Beryllium is used in lightweight metals, especially in valves in the aeronautical and space industries. Chronic Beryllium Disease (CBD) may occur among people who are exposed to dust or fumes from beryllium metal, metal oxides, alloys, ceramics, or salts. It occurs when people inhale beryllium in these forms. CBD usually has a very slow onset, and even very small amounts of exposure to beryllium can cause the disease in some people. Acute beryllium disease usually has a quick onset and has symptoms that resemble those of pneumonia or bronchitis. The acute form of the disease is believed to occur as a result of exposures well above the current PEL. This form of beryllium disease is now rare.

Recent data suggest that exposures to beryllium, even at levels below the 2 μg/m^3 PEL, may have caused CBD in some workers. Therefore, employers should consider providing their beryllium-exposed workers with air-purifying respirators equipped with 100-series filters (either N-, P-, or R-type) or, where appropriate, powered air-purifying respirators equipped with HEPA filters, particularly in areas where material containing beryllium can become airborne.[8]

Copper-Related Illnesses

The primary methods of entry into the body for occupational copper exposure are through inhalation or absorption through the eyes or skin. Short-term exposure to copper fumes causes irritation of the eyes, nose, and throat, and a flu-like illness called *Metal Fume Fever* can result. Metal Fume Fever

symptoms include fever, muscle aches, nausea, chills, dry throat, cough, and weakness. It may also include a metallic or sweet taste in the mouth of the affected employee. Long-term exposure to copper fumes due to repeated exposure may cause the skin and hair to change color.NIH[9]

The OSHA PEL for copper fume is 0.1 mg/m^3 (8 h-TWA). The OSHA PEL for copper dust and mist is 1.0 mg/m^3. Initial medical screening for employees potentially exposed to copper should include a thorough history of chronic respiratory diseases and *Wilson's disease* (hepatolenticular degeneration).

Cadmium-Related Illnesses

Acute exposure to cadmium can cause delayed pulmonary edema and acute renal failure after inhalation of high concentrations of the fume. Chronic exposure to cadmium dust and fume is toxic primarily to the kidneys with secondary effects on the bones (osteomalacia). Biological monitoring of cadmium-exposed workers is mandated by OSHA to prevent chronic renal disease. Studies have shown the latency period to be approximately 10 years.

High-risk occupational exposures are due to[10]:

- Brazing using cadmium-based solder
- Machining or welding on cadmium-alloyed or cadmium-plated steel
- Making cadmium-containing products
- Plating metal with cadmium
- Reclaiming scrap metals containing lead, cadmium, beryllium, and mercury
- Removing cadmium coatings
- Smelting or casting lead
- Smelting or refining zinc and copper

The OSHA PEL for an 8-h shift is 5 μg/m^3. The *action level* established by OSHA is 2.5 μg/m^3. The OSHA standard for cadmium is 29 CFR 1910.1027.

Chromium-Related Illnesses

Chronic exposure to chromium in the occupational environment most often results in contact dermatitis and ulcerations of the skin and nasal mucosa. Hexavalent chromium is the most toxic form of chromium. Inhalation of chromium dust, mist, or fumes can produce acute bronchoconstriction, probably through a direct irritant mechanism. Industrial uses of hexavalent chromium compounds include chromate pigments in dyes, paints, inks, and plastics; chromates added as anticorrosive agents to paints, primers, and other surface coatings; and chromic acid electroplated onto metal parts to provide a decorative or protective coating. Hexavalent chromium can also be

formed when performing "hot work" such as welding on stainless steel or melting chromium metal. In these situations, the chromium is not originally hexavalent, but the high temperatures involved in the process result in oxidation that converts the chromium to a hexavalent state.[11]

High-risk occupational exposures to chromium are due to:

- Welding stainless steel
- Heating or machining chromium alloys
- Mining or crushing chromium ores
- Plating metal with chromium
- Producing chromium alloys or chromate pigments
- Removing chromate-containing paints by abrasive blasting
- Spraying and sanding chromate-containing paints
- Using chromates or dichromates in printing
- Using chromates or dichromates in tanning
- Working as a cement floorer with exposure to chromate salts

The OSHA PEL for hexavalent chromium is 5 $\mu g/m^3$ for an 8-h TWA.

Coal Dust-Related Illnesses

Coal workers' pneumoconiosis (also known as Black Lung Disease) is a lung disease caused by inhaling coal mine dust. Although some miners never develop the disease, others may develop the early signs after less than 10 years of mining experience. According to recent studies by the National Institute for Occupational Safety and Health (NIOSH), about one of every 20 miners participating in our program has X-ray evidence of some pneumoconiosis.

In its early stages, called simple pneumoconiosis, the disease may not prevent an employee from working or carrying on most normal activities. In some miners, the disease never becomes more severe. In other miners, the disease progresses from simple to complicated pneumoconiosis, a condition also called progressive massive fibrosis.

Unfortunately, there is no cure for the damage that the dust has already done to the lungs. However, preventing coal workers' pneumoconiosis is among the highest priorities in protecting the health of the coal miner.NIH[12]

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for the respirable fraction of coal dust (less than 5% silica) is 2.4 mg/m^3 time-weighted average (TWA) concentration.

Cobalt-Related Illnesses

Acute exposure: Acute exposure to cobalt metal, dust, and fume is characterized by irritation of the eyes and, to a lesser extent, irritation of the skin. In sensitized individuals, exposure causes an asthma-like attack, with

wheezing, bronchospasm, and dyspnea. Ingestion of cobalt may cause nausea, vomiting, diarrhea, and a sensation of hotness.

Chronic exposure: Chronic exposure to cobalt metal, dust, or fumes may cause respiratory or dermatologic signs and symptoms. Following skin sensitization, contact with cobalt causes eruptions of dermatitis and increases in frictional surfaces of the arms, legs, and neck. Following sensitization of the respiratory system, cobalt exposure causes obstructive lung disease with wheezing, cough, and shortness of breath. Chronic respiratory exposure results in reduced lung function, increased fibrotic changes on chest X-ray, production of scanty mucoid sputum, and shortness of breath. Chronic cobalt poisoning may cause polycythemia, hyperplasia of the bone marrow and thyroid gland, pericardial effusion, and damage to the alpha cells of the pancreas. High-risk occupational exposures to cobalt are[13]:

- Machining cobalt alloys
- Manufacturing cemented carbide materials or tools
- Using cemented carbide materials or tools

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for cobalt metal, dust, and fume (as Co) is 0.1 mg/m^3 of air as an 8-h time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1].

Formaldehyde-Related Illnesses

Studies indicate that formaldehyde is a potential human carcinogen. Formaldehyde is a colorless, strong-smelling gas. Commonly used as a preservative in medical laboratories and mortuaries, formaldehyde is also found in other products such as chemicals, particle board, household products, glues, permanent press fabrics, paper product coatings, fiberboard, and plywood. It is also widely used as an industrial fungicide, germicide, and disinfectant.

Workers can inhale formaldehyde as a gas or vapor or absorb it through the skin as a liquid. They can be exposed during the treatment of textiles and the production of resins. Besides healthcare professionals and medical lab technicians, groups at potentially high risk include mortuary employees as well as teachers and students who handle biological specimens preserved with formaldehyde or formalin.[14]

The permissible exposure limit (PEL) for formaldehyde in all workplaces (including general industry, construction, and maritime, but not in agriculture) covered by the OSH Act is 0.75 ppm measured as an 8-h time-weighted average (TWA). The standard includes a 2-ppm short-term exposure limit (STEL) (i.e., maximum exposure allowed during a 15-min period). The "action level" is 0.5 ppm measured over 8 h. The OSHA standard for formaldehyde is 29 CFR 1910.1048.

Lead-Related Illnesses

Workers are exposed to lead by breathing in lead dust or fumes from work activities, or particles of lead may be swallowed from eating, drinking, or smoking in lead-contaminated areas. Workers may also take home lead dust on their skin, hair, work clothes, and boots. When lead enters the body, it can be stored in bones and tissues for a very long time. This means that lead can build up in the body and cause harm in the long term. Early effects of lead poisoning may be hard to detect. However, employer training and awareness programs can help workers recognize symptoms and seek prompt medical attention.[15]

Health effects related to occupational exposure to lead are:

- Brain disorders
- Anemia
- Brain and nerve disorders
- High blood pressure
- Kidney disorders
- Reproductive disorders
- Decreased red blood cells
- Slowed reflexes

The OSHA 8-h PEL is 50 μg/m^3. For those exposed to air concentrations at or above the action level of 30 μg/m^3 for more than 30 days per year, OSHA mandates periodic determination of blood lead levels. If a blood lead level is found to be greater than 40 μg/dL, the worker must be notified in writing and provided with a medical examination. If a worker's one-time blood lead level reaches 60 μg/dL (or averages 50 μg/dL or more on three or more tests), the employer is obligated to remove the employee from excessive exposure, with maintenance of seniority and pay, until the employee's blood lead level falls below 40 μg/dL. The OSHA standard for occupational exposure to lead is 29 CFR 1910.1025. OSHA's lead standard can be found in 29 CFR 1910.1025.

Manganese-Related Illnesses

Workers exposed to Mn have higher average urine and blood levels than unexposed workers, but these tests will not predict disease severity in a particular case. Similarly, abnormalities in the globus pallidus of the brain by MRI study reflect recent exposure to Mn, but are not diagnostic of disease. Neuropsychological testing can identify workers with advanced disease. Symptoms first appear after chronic exposure of at least several months in duration:

1) *Prodromal phase*: Evidence of cognitive dysfunction and emotional disturbances begins to occur prior to severe motor and neurological dysfunction; symptoms may include fatigue, anorexia, muscle pain, nervousness, irritability, violent outbursts, insomnia, decreased libido, and labile affect; workers may also report headache, hypersomnia, spasms, weariness of the legs, and arthralgias.
2) *Intermediate phase*: Compulsive uncontrollable laughter or crying, clumsiness of movement, exaggeration of reflexes in lower limbs, speech disorders, visual hallucinations, excessive sweating, excessive salivation, and confusion.
3) *Established phase*: Muscular weakness, difficulty in walking, stiffness, impaired speech, mask-like face, increased muscular tone, slow and shuffling gait, micrographia, and resting tremors; the syndrome is indistinguishable from Parkinson's disease; Parkinsonism caused by manganese has the following that distinguish it from Parkinson's disease: psychiatric symptoms early in the disease; cock walk; tendency to fall backward; less frequent resting tremor; more frequent dystonia; lack of response to dopaminomimetics; abnormal MRI showing manganese in the pallidum and caudate nucleus; and normal fluorodopa positron emission tomography scan. Characteristic findings of manganese poisoning are poor steadiness of hands, difficulty doing rapid alternating movements, muscular rigidity, and postural instability. Urine and plasma Mn levels are ineffective biomarkers. Blood Mn may reflect average elevated daily air Mn levels when exposures are ongoing and relatively consistent.[16]

High-risk occupational exposures to manganese are:

- Machining manganese alloys
- Mining or crushing manganese ores
- Using ferromanganese in alloy production
- Using manganese-containing welding rods

The OSHA 8-h PEL for manganese (dust) is 5 mg/m^3.

Mercury-Related Illnesses

Mercury can cause peripheral neuropathy and neuropsychiatric disorders after chronic exposure. Inhalation of elemental mercury vapor is the most common exposure route leading to occupational mercury poisoning. The key to preventing chronic mercury poisoning is to reduce spills and to clean up ones that occur. Other forms of mercury poisoning follow the ingestion of inorganic mercury and organic mercury compounds.

High-risk occupational exposures to mercury include[17]:

- Extracting mercury ore
- Fabricating measuring devices containing mercury
- Manufacturing and repairing mercury fluorescent lights
- Manufacturing or using mercury dental amalgams
- Reclaiming scrap metal containing lead, cadmium, beryllium, or mercury
- Using mercury to extract gold
- Working in the mercury cell room in a chlor-alkali plant

The OSHA PEL for an 8-h TWA is 0.01 mg/m^3, with a ceiling limit of 0.04 mg/m^3.

Pneumoconiosis

Pneumoconiosis is a group of interstitial lung diseases caused by the inhalation of certain dusts and the lung tissue's reaction to the dust. The principal cause of pneumoconiosis is workplace exposure. The primary pneumoconioses are asbestosis, silicosis, and coal workers' pneumoconiosis. As their names imply, they are caused by inhalation of asbestos fibers, silica dust, and coal mine dust. We have already discussed asbestos-related illnesses. Therefore, we will discuss the remaining two in the next sections.NIH[18]

Silica-Related Illnesses

As mentioned, silicosis is a pneumoconiosis illness. Complicated silicosis refers to the development of progressive massive fibrosis (PMF), in which pulmonary nodules coalesce into larger conglomerations. PMF has been observed to develop in a small percentage of patients with simple chronic silicosis and a large percentage of patients with accelerated silicosis. Accelerated silicosis is similar to simple silicosis, but the disease develops after heavier exposure over a shorter time period. The latency is 2–5 years for accelerated silicosis, versus greater than 10 years for simple silicosis. Accelerated silicosis follows a course of increasing dyspnea. Silicosis is associated with an increased risk of autoimmune diseases.[19]

High-risk occupational exposures to silica are:

- Blasting, drilling, removing, or crushing rock, concrete, or brick
- Grinding or cutting tiles, stones, concrete, bricks, or terrazzo
- Loading or dumping dusty rock, stone, or sand
- Making products from silica powder/stone or other fibrogenic minerals

- Use abrasives containing silica or silicon carbide
- Use a hand-held saw or grinder to remove brick mortar

The OSHA 8-h Permissible Exposure Limit (PEL) is 50 μg/m^3 and the Action Level (AL) for silica exposure is 25 μg/m^3.

Zinc-Related Illnesses

Zinc is a metal that is normally found in small amounts in nature. It is used in many commercial industries and can be released into the environment during mining and smelting (metal processing) activities. People living near smelters or industries using zinc could be exposed to higher levels of zinc by drinking water, breathing air, and touching soil that contains the metal. Exposure to high levels of zinc over long periods of time may cause adverse health effects.

A short-term illness called *metal fume fever* can result if workers breathe very high levels of zinc dust or fumes. This condition, which usually lasts from 24 to 48 h, causes chills, fever, excessive sweating, and weakness. Long-term effects of breathing zinc dust or fumes are not known.[20]

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for zinc oxide is 15 mg/m^3 of air for total dust and 5 mg/m^3 for the respirable fraction as an 8-h time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1].

Aluminum-Related Illnesses

Aluminum dust is an eye and respiratory tract irritant in humans. Soluble aluminum salts are irritants when inhaled as aerosols. Although inhalation of aluminum powder of particle size 1.2 μm, given over 10- or 20-min periods several times weekly, resulted in no adverse health effects among thousands of workers over several years, several other studies report X-ray evidence of pulmonary fibrosis. Some patients on long-term hemodialysis develop speech disorders, dementia, or convulsions. This syndrome is associated with increased concentrations of aluminum in serum, brain, muscle, and bone. There is some evidence that Alzheimer's disease may be linked to aluminum content in the body. Analysis of the aluminum content in the brains of persons dying from Alzheimer's has shown increased levels, although brain aluminum levels vary greatly. A second correlating factor is that neurofibrillary tangles (NFTs) have been identified in both aluminum encephalopathy and in Alzheimer's disease. However, it has been shown that the NFTs produced by the two conditions are structurally and chemically different and that NFTs are present in several other neurological disorders. It appears that the aluminum content of the brain is less an issue relating to exposure to aluminum than an issue of a blood–brain barrier defect or compromise of some kind.[21]

High-risk occupational exposures to aluminum are:

- The processing and transportation of aluminum
- Melting or soldering of electrical transmission lines
- Used in the construction, manufacturing, explosives, petrochemical, and paper industries
- Used in desalination, cryogenic technology, permanent magnets, and as a substitute for copper
- Used in testing for gold, arsenic, and mercury
- Use in sugar refining, alloying metals, as a chemical intermediate, and in containers for fissionable reactor fuels

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for aluminum is 15 mg/m^3 of air for total dust and 5 mg/m^3 for the respirable fraction, as an 8-h time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1].

Antimony-Related Illnesses

Antimony is a silvery-white metal that is found in the earth's crust. Antimony ores are mined and then mixed with other metals to form antimony alloys or combined with oxygen to form antimony oxide.

Little antimony is currently mined in the United States. It is brought into this country from other countries for processing. However, there are companies in the United States that produce antimony as a by-product of smelting lead and other metals.

Antimony isn't used alone because it breaks easily, but when mixed into alloys, it is used in lead storage batteries, solder, sheet and pipe metal, bearings, castings, and pewter. Antimony oxide is added to textiles and plastics to prevent them from catching fire. It is also used in paints, ceramics, fireworks, and as enamels for plastics, metal, and glass.

Exposure to antimony at high levels can result in a variety of adverse health effects. Breathing high levels for a long time can irritate your eyes and lungs and can cause heart and lung problems, stomach pain, diarrhea, vomiting, and stomach ulcers.

Ingesting large doses of antimony can cause vomiting. We don't know what other effects may be caused by ingesting it. Long-term animal studies have reported liver damage and blood changes when animals ingested antimony. Antimony can irritate the skin if it is left on it. Antimony can have beneficial effects when used for medical reasons. It has been used as a medicine to treat people infected with parasites.[22]

The Occupational Safety and Health Administration (OSHA) has set an occupational exposure limit of 0.5 mg of antimony per cubic meter of air (0.5 mg/m^3) for an 8-h workday and a 40-h workweek.

Exposure to antimony occurs in the workplace or from skin contact with soil at hazardous waste sites. Breathing high levels of antimony for a long time can irritate the eyes and lungs and can cause problems with the lungs, heart, and stomach.

Dust-Related Illnesses

Excessive dust in the workplace can be highly dangerous on a number of levels. Firstly, although rare, a cloud of concentrated dust is potentially combustible and can, therefore, cause explosions, so it is important that companies keep their working environments as relatively dust-free as possible to avoid such potential catastrophes. However, the most common problem associated with dust in the workplace arises from dust-related illnesses, which have been one of the major occupational diseases identified.

Common Environments for Contracting Dust-Related Illnesses

All workplaces need to carry out cleaning duties and pay particular attention to hygiene issues; for the most part, in places such as an office, for example, dust should not present too much of a problem. However, there are many industries which need to be especially vigilant. Here is a list of some of the more common working environments where excess dust can create a real problem.

- Mines and quarries—dust from coal, flint, and silica
- Construction sites—dust from cement and asbestos
- Farming and agriculture—dust from grain
- Carpentry and joinery—dust from wood
- Bakeries and mills—dust from flour
- Textiles—dust from materials like leather

Workers can suffer from a variety of illnesses and medical conditions as a result of working in dust-filled environments. Depending on the nature of the work, some of these ailments can become more serious than others. The range of dust-related industries and conditions encompasses eye and nose damage, rashes, and other conditions, asthma, silicosis, asbestosis, mesothelioma, and lung cancer related to asbestos. Pneumoconiosis, which is the name given to diseases such as those caused by asbestosis and silicosis, is a broad term that describes any condition affecting the lungs causing inflammation or scarring of the lung tissue. One of the major worries is that it can

often take several decades for a person to develop any symptoms of pneumoconiosis, which can manifest in things like excess coughing, breathing difficulties, and even weight loss.

The current OSHA 8-h PEL for PONR (Particulates Otherwise Not Regulated) respirable fraction is 5.0 mg/m^3 and 15 mg/m^3 for total particulates.

Thallium-Related Illnesses

Pure thallium is a bluish-white metal that is found in trace amounts in the earth's crust. In the past, thallium was obtained as a by-product from smelting other metals; however, it has not been produced in the United States since 1984. Currently, all the thallium is obtained from imports and from thallium reserves.

In its pure form, thallium is odorless and tasteless. It can also be found combined with other substances such as bromine, chlorine, fluorine, and iodine. When it is combined, it appears colorless to white or yellow.

Thallium is used mostly in manufacturing electronic devices, switches, and enclosures, primarily for the semiconductor industry. It also has limited use in the manufacture of special glass and for certain medical procedures.

The current OSHA 8-h PEL for thallium is 0.1 mg/m^3. Thallium is also designated by OSHA as a skin hazard.[23]

Pesticide-Related Illnesses

Organophosphate and N-methyl carbamate insecticides cause accumulation of acetylcholine at nerve endings by poisoning the acetylcholinesterase enzyme. In carbamate poisoning, the inhibition of the enzyme is rapidly reversible, and the workers often improved by the time of arrival at the clinic or emergency room. Organophosphates (OPs) can irreversibly bind to the enzyme, so that normal enzyme activity can only be restored after the cells synthesize new acetylcholinesterase. This process takes up to 60 days. The primary route of occupational exposure is through the skin. Some of the health effects associated with pesticides are diarrhea, urination, miosis, bradycardia, emesis, lacrimation, salivation, secretions, and sweating. The primary route of occupational exposure is through the skin.NIH[24]

High-risk occupational exposures to pesticides are:

- Apply organophosphates or work in fields after an application
- Work with toxic chemicals that could be spilled or released

The current OSHA 8-h TWA PELs for pesticides are chemical-specific and are available on the MSDS or in 29 CFR 1910.1000 Table Z-1.

Key Information to Remember on Toxicology

1. Ames testing is a procedure to determine whether or not a chemical is a mutagen.
2. Aluminum used in bauxite ore can cause lung cancer, emphysema, and pneumoconiosis.
3. Asbestos used as insulation and in numerous other products can cause asbestosis, lung cancer, and mesothelioma.
4. Arsenic from abrasive blasting can cause lung cancer or hemoglobinuria.
5. Benzene can cause granulocytic leukemia or myelogenous leukemia.
6. Beryllium from ore processing can cause Chronic Beryllium Disease (CBD) or Berylliosis.
7. Cadmium from abrasive blasting can cause renal damage.
8. Creosote coal tar from wood preservatives causes lung cancer.
9. Chromium exposure can lead to the development of lung cancer.
10. Cobalt causes hard metal disease or lung cancer.
11. Nickel causes lung and nasopharyngeal cancer.

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5. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic? tbl=TblAgents&id=5.
6. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=255.
7. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=36.
8. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=26.
9. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=374.

10. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=6.
11. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=17.
12. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=117.
13. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=37.
14. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=271.
15. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=10.
16. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=39.
17. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=13.
18. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=552.
19. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=260.
20. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=69.
21. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=287.
22. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=58.
23. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblAgents&id=65.
24. National Institute of Health. http://hazmap.nlm.nih.gov/cgi-bin/hazmap_generic ?tbl=TblDiseases&id=66.

8

Industrial Hygiene Air Sampling

Industrial hygiene is the science and art dedicated to the anticipation, recognition, evaluation, and control of workplace hazards that may cause worker injuries or illnesses. Today's industrial hygienist is a person trained and educated in physics, biology, chemistry, safety, engineering, or environmental sciences. In addition, a Certified Industrial Hygienist (CIH) is someone with the requisite education, who has applied to the American Board of Industrial Hygiene (ABIH) and who has successfully completed an examination. The industrial hygienist must have a broad spectrum of knowledge in safety, ventilation, illumination, radiation, biological sciences, noise, ergonomics, thermal stressors, and a wide variety of other topics. Each of these topics will be discussed in detail within their own individual chapters. The industrial hygienist, while concerned with physical safety, focuses on the prevention of worker illnesses caused by workplace exposures to various chemicals, substances, and elements.

Anticipation of Hazards

The industrial hygienist must be capable of anticipating workplace hazards. Before ever arriving at a job site or facility, the industrial hygienist can perform preliminary research to determine the type of work and potential exposures that may be present. This can be achieved by asking and answering the following questions:

- What type of facility or site is it?
- What types of operations or processes are being performed?
- What hazardous materials are present or likely to be present?
- Are facility schematics or drawings available for review?
- What standard operating procedures are available?
- Are MSDSs available for review?

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Recognition of Hazards

This phase of the assessment process is conducted primarily through walkthrough inspections by the industrial hygienist. This process is more qualitative than quantitative in nature. During the walkthrough inspection, the industrial hygienist will begin to identify the specific processes and operations and the potential hazards that each may pose to workers. Once the walkthrough inspection has been completed, the industrial hygienist will develop a strategy to further evaluate the extent each hazard poses.

Evaluation of Hazards

The evaluation process may require the use of specialized sampling equipment to quantify the workers' exposure to specific hazards. Depending on the type of hazard, representative samples will be collected using various methodologies that will be discussed in this chapter. Once samples have been analyzed by an accredited laboratory, the industrial hygienist will formulate a plan to control the hazards.

Control of Hazards

Once the plan to control the hazards has been established, the industrial hygienist will develop a plan of action to eliminate, minimize, or mitigate the hazards, which may include engineering controls, administrative controls, or personal protective equipment. Through the elimination or mitigation of a hazard, the risk to the employee can be drastically reduced.

Definitions

Vapors: A gaseous form of a substance that is normally a solid or liquid at room temperature.

Gases: Substances that completely occupy a space and can be converted to a liquid or solid by increasing or decreasing the temperature.

Vapor pressure: The pressure that a vapor at equilibrium with a pure liquid at a given temperature exerts on the surrounding atmosphere.

Particulate: Fine solid or liquid particles, such as dust, fog, mist, smoke, or spray.

Dust: Solid particles generated by mechanical action (crushing, grinding, etc.). Size ranges are usually from 0.1 to 30 μm.

Fume: Airborne solid particles formed by condensation of vapor (i.e., welding fumes). Sizes range from 0.001 to 1.0 μm.

Mist: Suspended liquid droplets generated by condensation or atomization (fogs are formed by condensation). Sizes range from 0.01 to 10 μm.

Fibers: Particulate with an aspect ratio (length to width) of 3:1.

Air Sampling

There is a wide variety of industrial hygiene sampling equipment available for air sampling. The variety is such that each and everyone cannot be discussed. In this chapter, we will discuss the types and applications of the most commonly used equipment and media.

There are several reasons why air sampling and testing are conducted. They may include the following:

- To determine compliance with regulations
- To assess worker exposure to determine if personal protective equipment being used is adequate
- To monitor implemented control measures
- To evaluate contaminant emissions
- Documentation for legal reasons

The types of air sampling that can be performed include the following:

- *Grab sampling*: It can be performed using direct-reading instruments or a known volume of air collected in a container, such as a Tedlar bag, and sent to a laboratory.
- *Personal sampling*: An employee wears a sampling device, such as a pump, which draws air across a filter medium for sample collection, which is sent to a laboratory. This is the preferred method of sampling when evaluating worker exposure.
- *Area sampling*: It uses the same type of media as in personal sampling; however, the sampling device and media are stationary inside a room.
- *Integrated sampling*: Integrated sampling is collecting one or more personal air samples in order to estimate the workers' 8-h time-weighted average exposure.

- *Direct reading*: Direct-reading instruments are calibrated for specific contaminants. Air samples are drawn into the direct-reading instrument and analyzed by several methods, including, but not limited to, fiber optics, photoionization detection, or flame ionization detection methods.[1]

Sampling Methodology

Sampling methodologies are most frequently determined by the National Institute for Occupational Safety and Health (*NIOSH Manual of Analytical Methods*), which is available in hard copy or can be located at http://www.cdc.gov/niosh/docs/2003-154/. Another source to use when making preliminary plans to conduct air sampling is the analytical laboratory itself. The selection of the laboratory is a critical step in the sampling process. It is highly recommended that you use an American Industrial Hygiene Association (AIHA)-accredited laboratory. By using an AIHA-accredited laboratory, you are assured of the laboratory quality assurance/quality control and ultimately the validity of the sample analysis. The AIHA laboratory director can also serve as a great resource when attempting to determine the methodology of choice for your particular work environment. One other source to refer to regarding sampling methodologies is the Occupational Safety and Health Administration (OSHA) Index of Analytical Methods available at the following Internet address: http://www.osha.gov/dts/sltc/methods/toc.html.

Equipment Selection

The methodology chosen for the sampling dictates the type of equipment used in the collection of air samples. The equipment of choice is based on the methodology and the contaminant that you are sampling for. Is the contaminant a gas, vapor, mist, fume, or particulate? Are you sampling for respirable or total portions of the sample? These are questions that need to be determined prior to sampling. We will now discuss the types of sampling equipment used in air sampling.

Air Sampling Pumps

Air sampling pumps are one of the most common types of equipment used to collect both personal and area samples. They can be classified as either low-volume or high-volume sampling pumps, or personal or area sampling pumps, respectively. Low-volume air sampling pumps can range from 100 to 5000 cc/m (0.1–5 lpm), whereas most high-volume air sampling pumps have an adjustable flow rate of 5000 to 30,000 cc/m (5–30 lpm). Low-volume

pumps are typically used to collect personal samples, while high-volume air sampling pumps are used to collect area samples. Both types of air sampling pumps draw volumes at known flow rates through a filter/media by means of a pump. Some of the air sampling pumps used in industrial hygiene sampling have a "critical orifice," which is a hole of specific measurement drilled into a plate to create a constant flow rate.

Piston and Bellows Air Pumps

A piston-type pump uses a handheld pump similar to the operation of a bicycle pump to draw a known volume of air across an absorbent tube designed for specific contaminants. A bellows-type pump is used for the same purposes as the piston-type pump. Both piston and bellows pumps are used primarily for screening purposes during walkthrough surveys of a facility to make an initial assessment of potential exposures.

Direct-Reading Instruments

Direct-reading instruments are valuable tools for detecting and measuring worker exposure to gases, vapors, aerosols, and fine particulates suspended in the air. These instruments permit real-time or near real-time measurements, and their use is specifically required by some OSHA standards. There are many types of instruments available, each of which is designed for a specific monitoring purpose. Proper operation of direct-reading instruments is essential to ensure that accurate information is obtained when evaluating air contaminants.[1]

One type of direct-reading instrument is the multi-gas meter used in confined space air sampling prior to and during entry. The multi-gas meter uses various sensors installed inside the meter and may include oxygen, sulfur dioxide, carbon monoxide, carbon dioxide, hydrogen sulfide, and combustible gases. It is imperative that these meters be zeroed and calibrated prior to each use to ensure the accuracy of the meter. The manufacturer's operating instructions should be read, understood, and followed. Operators of multi-gas meters should be thoroughly trained. All too often, operators have a 5 or 10-min instruction period and are expected to understand the operation and interpretation of data. As a safety professional, part of your responsibility is to ensure that adequate training is performed.

- Note: When working in a potentially explosive environment, ensure that all sampling equipment is classified by the manufacturer as "intrinsically safe" prior to use.

Cyclones

On occasion, when sampling, various apparatus are to be used in conjunction with the air sampling pumps. To be discussed in this section are cyclones. Cyclones are devices that discard larger particles. They are used in

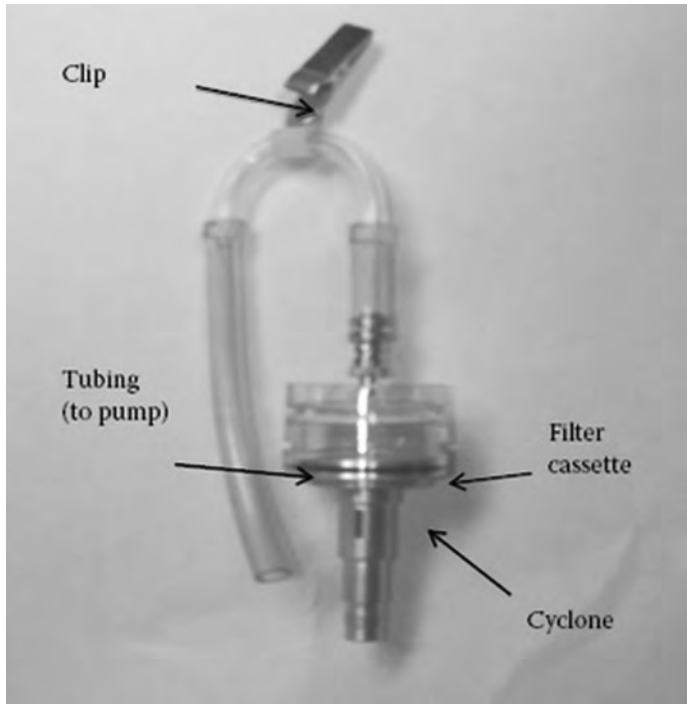


FIGURE 8.1
Cyclone-filter cassette configuration (Source: Yates, W. David, 2024).

conjunction with sampling filters and cassettes and air sampling pumps. An example of their use is when collecting samples for the respirable fraction of airborne particulates. The cyclone will discard particulates larger than 4.0 μm in diameter and deposit the respirable fraction onto the sampling media. A diagram of a cyclone configuration is shown in Figure 8.1.

Sampling Media

Just as in varied types of equipment, there are also varied types of sampling media used in air sampling. We will discuss some of the more common sampling media in this section.

Filters

Again, the specific filter used for sampling will depend on the sampling methodology chosen and the particular air contaminant that you are sampling. There is a wide variety of filters to select from, including the following:

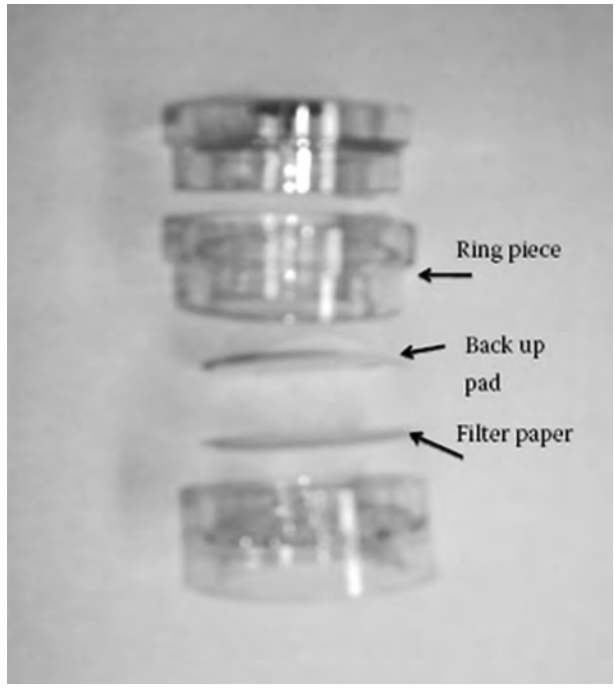


FIGURE 8.2
Example of a filter and cassette (Source: Yates, W. David, 2024).

- Polyvinyl chloride (PVC) filters
- Mixed cellulose ester filters (MCEF)
- Glass filters
- Matched-weight filters
- Tare-weighted filters

Filters are used primarily to sample for particulates, such as total and respirable particulates, metals, lead, zinc, and so on. An example of a filter and cassette is shown in Figure 8.2.[2]

Sorbent Tubes

Sorbent tubes are glass-encapsulated tubes with various media inside. They are used primarily for sampling of gases and vapors. When using a sorbent tube to test for gases and vapors, take precautionary measures to prevent cuts when breaking the tips of the tube. A diagram of a sorbent tube is shown in Figure 8.3.[2]

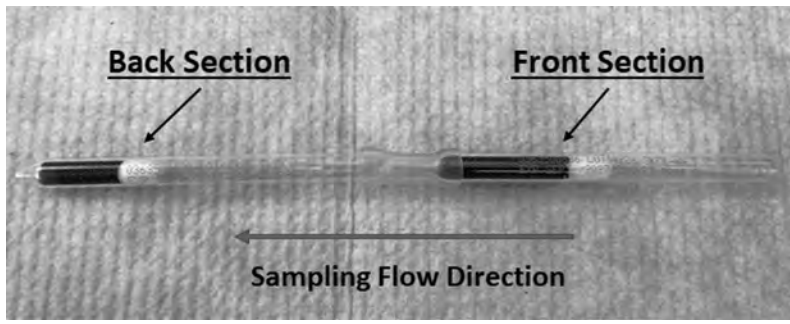


FIGURE 8.3
Photo of a sorbent tube (Source: From Occupational Safety and Health Administration, 2024. *"OSHA Technical Manual—Personal Sampling for Air Contaminants,"* https://www.osha.gov/otm/section-2-health-hazards/chapter-1).

Sample Collection Bags or Canisters

Sample collection bags or canisters are used to take grab samples of gases or vapors. Either positive or negative pressure can be used to fill the bags or canisters with the air from the sample location. The bag or canister is then sealed and sent to the laboratory for analysis.

Passive Samplers

Passive samplers are commercially available sample media worn by the worker as a badge. The collection process is controlled by a physical process such as diffusion through static air or permeation through a membrane, without using an air sampling pump. The badge is worn by an employee for a documented time (on and off times recorded) and then sealed and sent to a laboratory for analysis. A photo of a passive sampler is shown in Figure 8.4.[2]

Sampling Pump Calibration

One of the most important issues involving industrial hygiene air sampling is sample validity and reproducibility. Therefore, air sampling pumps must be pre- and post-sample calibrated using a primary standard or a secondary standard that is traceable to a primary standard. Examples of primary and secondary standards used in industrial hygiene sampling equipment calibration include the following:



FIGURE 8.4
Passive sampler (Source: Yates, W. David, 2024).

- Primary standards
- Spirometer
- Bubble burette
- Electronic soap bubble flow meter
- Secondary standards
- Wet test gas meter
- Dry gas meter
- Rotameters

In general, the procedure for calibrating air sampling pumps is listed below:

1. Ensure that the air sampling pump batteries are fully charged prior to calibrating.
2. Connect the inlet port of the air sampling pump to the filter media, as shown in Figure 8.5, via the tubing.
3. Connect the filter media, as shown in Figure 8.5, to the calibration device.
4. Inspect all connections.



FIGURE 8.5
Example of air sampling pump calibration configuration (Source: Yates, W. David).

5. Turn the air sampling pump to the "ON" position.
6. Wet the inside of the electronic bubble meter. *Note: This may take several trial runs to fully wet the inside of the meter.*
7. Once the inside of the meter is completely wet, such that the soap bubble is free-flowing, take a measurement by pressing the button on the electronic bubble meter.
8. If the measurement on the meter is not where you would like the flow rate to be, make the necessary adjustments on the air sampling pump. Repeat this step until your flow is as close to the desired rate as possible.
9. Take a minimum of three measurements, which should be ±2% of each other. Once three measurements within the ±2% range have been achieved, average the three readings. This is now your calibrated flow rate. Record this flow rate on the calibration sheet and the air sampling worksheet.
10. Disconnect the tubing from the filter media and the electronic bubble meter. Your pump is now calibrated and ready for use. *Note: The filter media used is only for calibration purposes and should not be used for sampling purposes.*
11. This procedure should be completed prior to sampling and after sampling has been completed to ensure that the flow rate is constant throughout the sampling process. The post-sampling calibrated flow should be within ±5% of the pre-calibrated flow rate. If the post-sampling flow rate is outside ±5% of the pre-sampling flow rate, the samples must be discarded.

Determining Minimum and Maximum Sample Volumes

Prior to collecting samples, it is necessary to determine the minimum and maximum volumes of air to collect in order to have a statistically valid sample. Before explaining how to calculate the minimum and maximum sample volumes, it is first necessary to define some terms. *The limit of detection* is the lowest level that can be determined to be statistically different from a blank sample. *The limit of quantification* is the concentration level above which quantitative results may be obtained with a certain degree of confidence. The limit of detection and the limit of quantification can be obtained from the analytical procedure or by consulting the analytical laboratory prior to sampling. *Target concentration* is an estimate of the airborne concentrations of the contaminant being tested. Previous data, direct-reading instruments, or professional judgment can be used to estimate the contaminant concentration. The *upper measurement limit* is the useful limit (milligrams of analyte per sample) of the analytical instrument (Dinardi,[3] p. 180). The minimum sample volume can be calculated using the following equation:

$$V_{\min} = \frac{\mathrm{LOQ} \times 10^3}{C_t},$$

where

$V_{\min}$ = minimum sample volume (L)
LOQ = limit of quantification (mg)
C_t = contaminant target concentration (mg/m^3)

For example, using NIOSH Analytical Method 2555, you would like to collect valid samples for acetone. Given a range of 2.7–295 µg and a target concentration of 420 ppm (1016.4 mg/m^3), what is the minimum sample volume required?

$$V_{\min} = \frac{0.0027\,\mathrm{mg} \times 10^3 \left(\frac{\mathrm{L}}{\mathrm{m}^3} \right)}{1016.4\,\mathrm{mg/m}^3}$$

$$= \frac{2.7\,\mathrm{L}}{1016.4}$$

$$= 0.003\,\mathrm{L}.$$

To calculate the maximum sampling volume, use the following equation:

$$V_{\max} = \frac{W_{\max} \times 10^3}{C_t},$$

where

V_{max} = maximum sample volume (L)

W_{max} = maximum analyte per sample (mg)

C_t = contaminant target concentration

Given the same information above and a W_{max} of 3 mg, what is the maximum sample volume to collect a statistically valid sample and to avoid sample breakthrough?

$$V_{max} = \frac{3.0\text{mg} \times 10^3 \text{L/m}^3}{1016.4\text{mg/m}^3}$$

$$= \frac{3000\,\text{L}}{1016.4}$$

$$= 2.95 \text{ or } 3.0\,\text{L}.$$

Determining the Minimum Number of Samples to Collect

One of the most commonly asked questions regarding air sampling is "How many samples do I need to collect to ensure compliance with exposure limits?" Table 8.1 illustrates a 90% confidence that one worker will be in the top 10% of the exposure within the group.

The Sampling Process

Once you have determined the contaminant you are sampling for, the methodology to use, the equipment to use, the appropriate media on which to collect the sample, and the number of samples to collect, you are ready to begin sampling. To collect air samples, perform the following steps:

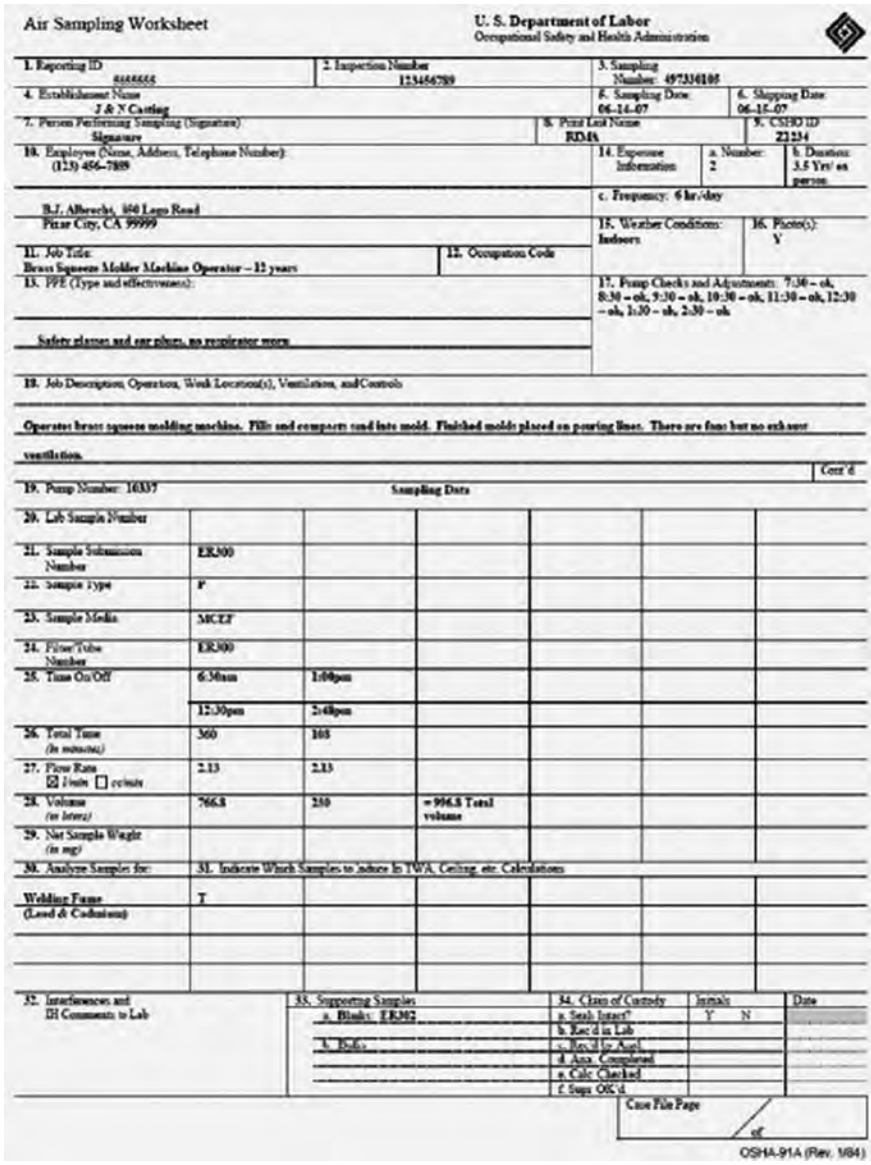
1. Assemble the sampling equipment.
2. Perform pre-sampling calibration in accordance with the previously mentioned procedures.
3. Record the calibration flow rates on the air sampling work sheet (see Figure 8.6).
4. Determine which employees are to be sampled.
5. Inform the employees to be sampled as to the purpose of the sampling and how it will affect them (i.e., wearing a personal pump, performing work in normal fashion, avoiding intentionally contaminating the sample, etc.).

TABLE 8.1

Table of Minimum Number of Samples to Collect

Employee Group Size (*N*)	1	2	3	4	5	6	7	8	9	10	11–12	13–14	15–17	18–20	21–24	25–29	30–37	38–49	50	a
Min. no. of samples collected	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	15	16	17	18	22

[a]*Exposure in the highest 10% of N.*



Air Sampling Worksheet

U. S. Department of Labor
Occupational Safety and Health Administration

1. Reporting ID: ######	2. Inspection Number: 123456789			3. Sampling Number: 457334105		
4. Establishment Name: J & N Casting				5. Sampling Date: 06-14-07	6. Shipping Date: 06-15-07	
7. Person Performing Sampling (Signature): Signature				8. Print Last Name: RDA	9. CSHO ID: Z2234	
10. Employee (Name, Address, Telephone Number): (123) 456-7889				14. Exposure Information:	a. Number: 2	b. Duration: 3.5 Yrs/ea person
					c. Frequency: 6 hr./day	
B.J. Albrecht, 460 Lego Road Pixar City, CA 99999				15. Weather Conditions: Indoors	16. Photo(s): Y	
11. Job Title: Brass Squeeze Molder Machine Operator – 12 years		12. Occupation Code				
13. PPE (Type and effectiveness): Safety glasses and ear plugs, no respirator worn				17. Pump Checks and Adjustments: 7:30 – ok, 8:30 – ok, 9:30 – ok, 10:30 – ok, 11:30 – ok, 12:30 – ok, 1:30 – ok, 2:30 – ok		

18. Job Description, Operation, Work Location(s), Ventilation, and Controls

Operates brass squeeze molding machine. Fills and compacts sand into mold. Finished molds placed on pouring floor. There are fans but no exhaust ventilation.

Cont'd

19. Pump Number: 10337 — Sampling Data

20. Lab Sample Number						
21. Sample Submission Number	ER300					
22. Sample Type	F					
23. Sample Media	MCEF					
24. Filter/Tube Number	ER300					
25. Time On/Off	6:30am	1:00pm				
	12:30pm	2:48pm				
26. Total Time (in minutes)	360	105				
27. Flow Rate ☒ l/min ☐ cc/min	2.13	2.13				
28. Volume (in liters)	766.8	210	= 996.8 Total volume			
29. Net Sample Weight (in mg)						
30. Analyze Samples for:	31. Indicate Which Samples to Advise In TWA, Ceiling, etc. Calculations					
Welding Fume (Lead & Cadmium)	T					

32. Interferences and IH Comments to Lab	33. Supporting Samples	34. Chain of Custody	Initials	Date
	a. Blanks: ER302	a. Seals Intact?	Y N	
	b. Bulks:	b. Rec'd in Lab		
		c. Rec'd by Anal.		
		d. Anx. Completed		
		e. Calc. Checked		
		f. Supv. OK'd		

Case File Page ___ of ___

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FIGURE 8.6
Air sampling worksheet (OSHA Technical Manual) sample chain-of-custody.

6. Label the samples with an appropriate numbering system prior to placing them on the employees.
7. Record the individual's name, location of the sample (area and operation description), and employee identification number or last four digits of the social security number on the air sampling worksheet.
8. Place the pump securely on the employee with a belt or strap.
9. Run the sampling tube with the media on the end of it to the employee's breathing zone (i.e., in the region below the nasal passages or chest region). Take precautions when placing the tubing not to restrict the employee's movements.
10. When the employee is about to begin work or enter a contaminated area, turn the pump on and record the time on the air sampling worksheet.
11. Once the sampling is completed, remove the sample and seal the openings to the media. Record the time off on the air sampling worksheet.
12. Review the information provided on the air sampling worksheet for accuracy and thoroughness.
13. Package samples in accordance with instructions from the laboratory and prepare for shipping.
14. Retain copies of the air sampling worksheet and copies of the shipping documents, which will serve as a chain-of-custody to the laboratory.

Most personal sampling required by OSHA can be performed by trained technicians. However, some air sampling may require the services of a CIH. To locate a CIH, contact the ABIH for a list of practicing CIHs.

One of the most vital considerations in any sampling is that the information, methodology, and results may all be "fair game" in any legal proceedings. Therefore, a sample chain-of-custody that tracks the sample from the point of collection to the laboratory is required. This chain of custody ensures a level of confidence that the analytical results reported are true and accurate, and are the results from the actual samples received and that no tampering after collection has been done to the sample.

The person collecting the sample will initiate the chain-of-custody, and each person that the sample is passed to will sign that they received the sample and that they passed it along to the next person in the chain until the sample has reached the laboratory. Once the analysis of the sample has been completed, the original, completed copy of the chain-of-custody will be returned to the client for their records. Figure 8.7 is a representation of the information included in a typical chain-of-custody form.

Date Shipped	# of samples	Sample Type/Media		Project Name or Number	
Purchase Order No.		Contact		Telephone Number	
Turnaround Time ☐ Same Day ☐ 2 Day ☐ 1 Day ☐ STD		Special Instructions and/or Unusual Conditions:		☐ Fax results: ( ) ☐ Email results – Email	
For Lab Use Only:		**Sample # or Sample Area**	**Sample Date**	**Sample Volume (liters)**	**Analysis Requested**

CHAIN OF CUSTODY RECORD

SAMPLES HAVE BEEN SEALED FOR TRANSPORT AND DELIVERED TO LABORATORY VIA:	**Sign here to initiate chain of custody**
Carrier	**Date**

Date/Time	**Condition of Sample**	**Samples Received by:**	**Samples Released by:**

FIGURE 8.7
Sample chain-of-custody form (Source: Yates, W. David).

Industrial Hygiene Sampling and Record-Keeping Procedures

If you are a safety professional responsible for either collecting industrial hygiene samples or contracting the sampling to an outside industrial hygiene firm, record keeping is of the utmost importance. Furthermore, if you are employed by any sizeable company, keeping up with the required sampling and conducting qualitative and quantitative industrial hygiene assessment, the task can be overwhelming. Therefore, I strongly recommend some type of industrial hygiene software to not only maintain accurate records for the sampling and sample results. The following is a list and short discussion of a few commercially available software programs. Some of these I have personal

experience with, while others I'm only familiar with through an Internet search and strictly based on information provided from their websites. By listing or not listing the software here is by no means to be considered a recommendation or lack of a recommendation. Each program listed or not listed has its own uses, advantages, and disadvantages; therefore, you should conduct your own research to determine the best fit for your particular organization.

Before beginning your research into industrial hygiene software, and most definitely before purchasing, you should consider the following issues:

- *Budgetary constraints*: Most of the programs listed here can be very expensive, ranging from $30,000 to $125,000 depending on the various modules that are needed.
- *Expected performance*: It is extremely important to determine what your specific needs are when purchasing industrial hygiene software. Are you looking just for a program to record the samples that you have collected and analyzed? However, if you have hundreds of employees that require medical surveillance, hearing conservation audiograms, and various types of samples, you may need a more sophisticated software package. Do you want to record training inside the software package? These are just a few of the questions that you must ask yourself before beginning and purchasing the software.
- *Security:* This is a critical piece of the puzzle. I would strongly recommend that you get the Information Technology, Human Resources, and even the Legal staff involved early on in the process. Some of the information being input into the system may be covered either under the Health Insurance Portability and Accountability Act (HIPAA) Privacy Rule or even under a collective bargaining agreement (CBA). Simple information, such as birth dates, may be considered sensitive information, but may be required to accurately populate the software. For example, the frequency of chest X-rays for asbestos workers varies with age, and most of the software programs are triggered by birth dates. The information input into the system must be adequately secure, as many of them are cloud-based packages.

Spiramid

Headquartered in Chantilly, Virginia, Spiramid, LLC, was formed in 2001 to specialize in Environmental, Health, and Safety (EHS) Software. Some of the major features of the Spiramid software are as follows:

- Qualitative exposure assessment
- IH sample data management

- Chemical and physical stressor data management
- Equipment management
- Fit testing records
- SEG management

Spiramid can be purchased as a core group of modules with additional add-on modules. One of the features of this software is the automatic uploading using the LIMs application, which allows the laboratory to directly input analytical results into the software (http://spiramid.com/products/industrial-hygiene-software/).[4]

Medgate

Medgate is headquartered in Ontario, Canada, specializing in EHS software. Based on information from their website at http://www.medgate.com/software/industrial-hygiene/,[5] the major features of their software are as follows:

- Equipment management
- Monitoring
- Respirator fit testing
- Survey
- Laboratory requisition
- Qualitative exposure monitoring
- SEG management

Process MAP

A review of their website demonstrates that a module for industrial hygiene is part of a larger EHS program. You can visit their website at http://www.processmap.com/ehs-software/integrated-ehs-management-system/industrial-hygiene-management for a more thorough review.[6]

Interpretation of Industrial Hygiene Air Sampling Results

The first step in understanding what the air sampling results mean is to fully understand that the sampling conducted represents a snapshot of what is

Client ID : [redacted] Lab ID : [redacted] Air Volume : 1099.56 L
Date Sampled : 11/07/23 Date Analyzed : 12/02/23

Parameter	LOQ ug	Total ug	Conc	Units
Antimony	0.90	<0.90	<0.00082	mg/m3
Beryllium	0.015	<0.015	<0.000014	mg/m3
Cadmium	0.15	<0.15	<0.00014	mg/m3
Chromium	7.5	<7.5	<0.0068	mg/m3
Cobalt	0.45	<0.45	<0.00041	mg/m3
Copper	0.30	1.4	0.0013	mg/m3
Iron Oxide	11.	170	0.15	mg/m3
Lead	0.38	<0.38	<0.00034	mg/m3
Manganese	0.15	14	0.013	mg/m3
Molybdenum	0.15	<0.15	<0.00014	mg/m3
Nickel	0.30	<0.30	<0.00027	mg/m3
Vanadium	0.45	<0.45	<0.00041	mg/m3
Zinc Oxide	4.7	<4.7	<0.0042	mg/m3

FIGURE 8.8
Example Industrial Hygiene Sampling Lab Report (Welding Profile) (Source: Yates, W. David, 2024).

going on at the time of the sampling. Therefore, the first step is to ensure that normal operation or "worst-case" scenarios are being conducted at the time of the sampling. This will ensure that exposure monitoring represents those conditions, and any such sampling conducted thereafter will be at or below those levels. This requires extensive knowledge of the operations being performed by the employees, along with sound professional judgment.

In Figure 8.8, an example Industrial Hygiene Sampling Lab Report is provided for air sampling conducted and analyzed for a welding fume profile, which includes various contaminants (or analytes).

As can be seen in the report, the total volume (required for determining the concentration) is provided. What is not shown in the report and important in interpreting the lab results for the specific operation is the work shift of the actual welder. This is important because the identified concentration from the lab report should be compared to one of the exposure standards and always to the OSHA PEL, since it is the only one that is legally enforceable. However, comparison to other standards may also be made, depending on the needs of the operation, such as threshold limit values (TLVs).

Looking at this specific example, consider the iron oxide exposure, which has a concentration of 0.15 mg/m^3. Assume that this exposure concentration was for an 8-h day and then it should be compared to the OSHA PEL of 10 mg/m^3, therefore the employee was well below the PEL and the Action Level (AL) of 5 mg/m^3. Now, assume that the employee performs this task for 12 h per shift. The comparison becomes a little more complicated. The first step would be to modify the PEL of 10 mg/m^3, based on the 12-h work schedule. To do this, use the following equation:

$$\text{PEL}_{\text{modified}} = \frac{8 \text{ hours} \times \text{PEL}}{\text{total work hours}}$$

In this particular case, the work shift is 12 h, so plug the numbers into the equation as follows:

$$\mathrm{PEL}_{\mathrm{modified}} = \frac{8\ \mathrm{hours} \times 10\ \mathrm{mg/m^3}}{12\ \mathrm{hours}}$$

$$\mathrm{PEL}_{\mathrm{modified}} = 6.67\ \mathrm{mg/m^3}$$

Therefore, the new PEL and AL, respectively, is 6.67 mg/m^3 and 3.34 mg/m^3. The results are to be compared to these based on a 12-h work shift. Each analyte should be interpreted in a similar fashion.

Key Information to Remember on Industrial Hygiene Air Sampling

1. Industrial hygiene is the science and art dedicated to the anticipation, recognition, evaluation, and control of workplace hazards that may cause worker injuries and illnesses.
2. The reasons for conducting air sampling are to determine compliance with regulations, to assess worker exposures to determine if PPE is adequate, to monitor implemented control measures, to evaluate contaminant emissions, and to provide documentation.
3. Grab sampling is the collection of a known volume of air in a container for laboratory analysis or by a direct-reading instrument.
4. Personal sampling involves an employee wearing an air sampler while he or she performs their normal work routine.
5. Area sampling uses the same type of pump and media as in personal sampling, but the sampling device is stationary throughout the sampling period.
6. Integrated sampling involves collecting one or more samples and then combining them to estimate the workers' 8-h time-weighted average exposure.
7. When analyzing samples, it is highly recommended that you use an AIHA-accredited laboratory.
8. Before sampling, determine whether the contaminant is a gas, vapor, mist, fume, or particulate.
9. Filter media are used primarily to sample particulates, such as total and respirable particulates, metals, lead, zinc, and so on.
10. Sorbent tubes are used for sampling gases and vapors.

11. Air sampling pumps and direct-reading instruments must be pre- and post-sample calibrated using a primary standard or a secondary standard traceable to a primary standard.
12. If the post-sampling flow rate is outside the ±5% of the pre-sampling flow rate, the samples must be discarded.
13. The limit of detection is the lowest level that can be determined to be statistically different from a blank sample.
14. The limit of quantification is the concentration level above which quantitative results may be obtained with a certain degree of confidence.
15. Target concentration is an estimate of the airborne concentrations of the contaminant being tested.
16. When working in a potentially explosive environment, ensure that all sampling equipment is classified by the manufacturer as "intrinsically safe" prior to use.

References

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9

Ventilation

In order to reduce or eliminate any hazard from the work area, there are five methods that the safety professional must adhere to. These methods include Elimination, Substitution, Engineering Control, Administrative Control, and Personal Protective Equipment. As everyone knows, the best (permanent) method is to eliminate the hazard out of the workplace. One way to reduce or eliminate the concentration of hazardous materials from the workplace is through ventilation. Today's safety professional must have more than just a general knowledge of ventilation and ventilation systems. He or she must have an in-depth knowledge. Furthermore, the Associate Safety Professional (ASP)/Certified Safety Professional (CSP) exam candidate will be expected to answer numerous questions regarding ventilation on the examination. It is for this reason that this chapter on ventilation has been included. Using the Board of Certified Safety Professionals (BCSP) exam reference sheet[1], this chapter will walk through each equation and explain, in detail, the use and purpose of the equation and provide examples and solutions to various scenarios.

Purpose for Using Ventilation

The primary purposes for using ventilation are to (a) maintain an adequate oxygen supply, (b) control hazardous concentrations of chemicals, (c) remove odors, (d) control temperature and humidity, and (e) remove contaminants at the source, before they enter the workplace. By understanding how to use and control ventilation, the safety professional can successfully eliminate or greatly reduce any concentration of contaminants in the air.

Types and Selection of Ventilation

Ventilation is basically divided into three categories: *general*, *dilution*, and *local* ventilation.

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General Ventilation

General ventilation is primarily used for comfort, such as temperature, humidity, and odor control, such as the air conditioning and heating system in your home.

Dilution Ventilation

Dilution ventilation is a system designed to dilute contaminants by mixing fresh air with contaminated air. Dilution ventilation is used primarily in health and fire protection. The components of a dilution system include the source of air exhaust, the source of air supply, a duct system, and a method to filter and temper incoming air.

Dilution ventilation is used to control the following:

- Contaminants of moderate toxicity
- A large number of sources
- Intermittent exposures
- Where emission sources are well distributed

Local (Exhaust) Ventilation

Local (exhaust) ventilation systems are designed to control contaminants at the source before mixing with breathing air occurs. When selecting which type of ventilation system to design and install (especially in the industrial environment), use the following criteria to make the selection.

Local (exhaust) ventilation is used to control the following:

- Highly toxic substances
- Single-source emissions
- Direct worker exposures

Note: Energy is required to move air. Air is constantly in turbulence moving at 25 ft/min.

General Concepts of Ventilation Notes

1. Air movement results from difference in pressure.
2. Difference in pressure can be attained by heating or by mechanical means.
3. A temperature gradient contributes to the ventilation.

Principles of Air Movement

Calculating for Volumetric Air Flow

To begin to understand ventilation, it is necessary to understand the principles of air movement. Airflow rates are calculated by multiplying the velocity by the cross-sectional area of the hood or duct in which the air flows. This is represented mathematically as

$$Q = V \times A$$

where

Q = volumetric flow rate (expressed in cfm [cubic feet per minute])
V = velocity of the air (expressed in fpm [feet per minute])
A = cross-sectional area of duct (expressed in sf [square feet])

An example of this would be to calculate the volumetric flow rate of a duct, given the following information: The duct is a round duct measuring 8 in. in diameter and the measured flow rate is 378 fpm. The first step would be to calculate the cross-sectional area of the duct. *(Note: Remember to convert the unit of measurement into feet.)*

We determine that the radius (1/2 the diameter) is equal to 4 in. or 0.33 ft. Using the equation for the area of a circle, the duct cross section is 0.35 sf. Insert these data into the equation as follows:

$$Q = 378\,\text{fpm} \times 0.35\,\text{sf}$$

$$Q = 132.3 \text{ or } 132\,\text{cfm}$$

Calculating Static Pressure, Velocity Pressure, and Total Pressure

Air moves from an area of higher pressure to that of lower pressure. Exhaust fans work by pushing air upstream of the fan, thus lowering the pressure on the downstream side. This pressure differential causes air to flow into the hood or duct. This pressure created by the fan is referred to as *static pressure.* **Static pressure on the downstream side of the fan is positive and negative on the upstream side**. *Velocity pressure* is the pressure in the direction of flow necessary to cause the air at rest to flow at a given velocity. The *total pressure* on a ventilation system equals the sum of static and velocity pressure. Total pressure is written mathematically as

$$\text{TP} = \text{SP} + \text{VP}$$

where

TP = total pressure (in inches, water gauge)
SP = static pressure (in inches, water gauge)
VP = velocity pressure (in inches, water gauge)

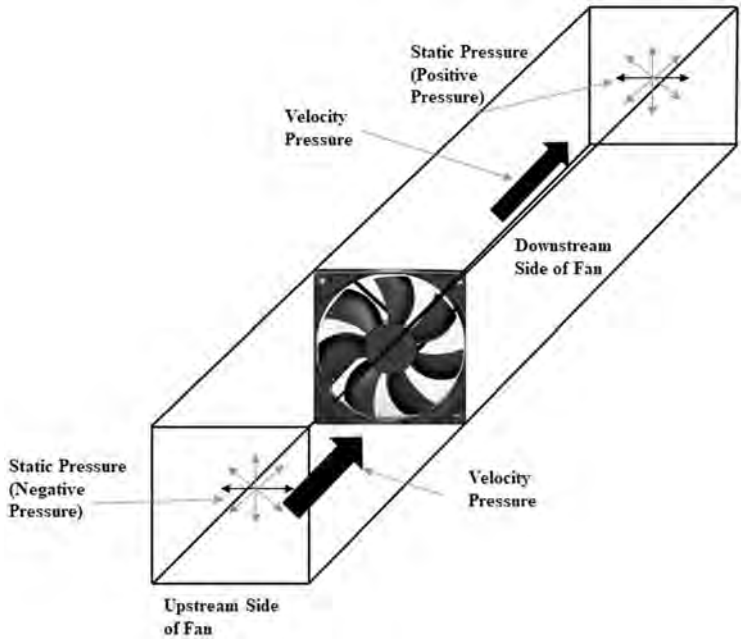


FIGURE 9.1
Illustration of static and velocity pressures inside a duct (Source: Yates, W. David 2024).

An illustration of both static and velocity pressure can be seen in Figure 9.1.

Calculating Velocity of Air

Another relationship to understand is the relationship between velocity and velocity pressure. Airflow velocity is important in various ways. Airflow velocity is used to capture contaminants and overcome cross-drafts, transportation of contaminants through the duct, and balancing of "losses" (as described previously in this chapter) in the system and in the discharge of the contaminant from the stack. This is described as the "magnitude" of the system, which is a function of the velocity pressure. This relationship is written mathematically as

$$V = 4005\sqrt{\text{VP}}$$

where
V = velocity (fpm)
VP = velocity pressure (H_2O)

Example

Given a velocity pressure of 0.2″, determine the velocity of air.

$$V = 4005\sqrt{0.2}$$

$$V = 4005(0.45)$$

$$V = 1802\,\text{fpm}$$

Contaminant Generation

When using dilution ventilation, it is important to understand that the flow rate of fresh air is determined by (a) contaminant generation, (b) proper mixing, and (c) target final concentration. The methods used apply to uniform rates of generation and low to moderate toxicity. The accumulation of contaminants is equal to the generation minus the removal. The following equation is used to determine the concentration buildup that will occur over a given period:

$$\ln\left(\frac{G - Q'C_2}{G - Q'C_1}\right) = \frac{Q^1(t_2 - t_1)}{V}$$

where

G = rate of generation of contaminant (cfm)
Q' = (Q/K)
K = design distribution constant (a constant factor [1–10])
C = concentration at a given time (parts per million [ppm])
V = volume of room or enclosure (ft^3)
Q = flow rate (cfm)
$t_2 - t_1$ = time interval or $\Delta\, t$

Example

Acetone is being generated under the following conditions: G = 1.4 cfm, Q' = 2500 cfm, V = 75,000 ft^3, C_1 = 0, and K = 2. How long will it take (in minutes) before the concentration reaches 175 ppm?

The question is straightforward and asks that we calculate for time, which is the unknown. We can use the above equation but must first manipulate it in order to obtain the desired outcome (time). We therefore set up the equation as follows:

$$\Delta t = \frac{V}{Q'}\left[\ln\left(\frac{G - Q'C_2}{G}\right)\right]$$

We can now insert the data from our example into the equation and solve for time, as follows:

$$\Delta t = \frac{75{,}000\ \text{ft}^3}{2500\,\text{cfm}}\left[\ln\left(\frac{1.4\,\text{cfm} - 2500\,\text{cfm}(0.000175)}{1.4\,\text{cfm}}\right)\right]$$

$$\Delta t = -30\left[\ln\left(\frac{0.9625}{1.4}\right)\right]$$

$$\Delta t = -30\left[\ln 0.6875\right]$$

$$\Delta t = -30\left(-0.3747\right)$$

$$\Delta t = 11.24 \text{ min}$$

Note**:** In the above equation, it was necessary to convert the concentration of 175 ppm to a decimal number. We did this by taking 175 and dividing by 10^6, with the result being 0.000175.

Simplified, it will take approximately 11.24 min for an area with zero concentration of acetone and a volume of 75,000 ft^3, generating 1.4 cfm of acetone and a Q' of 2500 cfm to reach a concentration of 175 ppm.

Example

Another example problem may ask you to calculate the concentration after an established timeframe. For example, given the same data as listed in the previous problem, what would be the concentration of acetone after 60 min?

Again, we must manipulate the original equation in order to obtain the requested information (concentration). We can use the original equation and manipulate it as follows:

$$C_2 = \frac{G\left[1 - e^{\left(\frac{Q'\Delta t}{V}\right)}\right]}{Q'} \times 10^6$$

Now, we can insert the known data from the previous problem, as follows:

$$C_2 = \frac{1.4\,\text{cfm}\left[1 - e^{\left(-\frac{2500\,\text{cfm}(60)}{75{,}000\,\text{ft}^3}\right)}\right]}{2500\,\text{cfm}} \times 10^6$$

$$C_2 = \frac{1.4\,\text{cfm}\left[1 - 0.1353\right]}{2500} \times 10^6$$

$$C_2 = \frac{1.4\,\text{cfm}\left(0.8647\right)}{2500\,\text{cfm}} \times 10^6$$

$$C_2 = 0.000484 \times 10^6$$

$$C_2 = 484.2\,\text{ppm}$$

Given the criteria for the equation in the previous problem, you can see that after 60 min, the concentration of acetone will be 484.2 ppm.

Calculating Purge Rates

Assuming the air in a room is contaminated, but the generation of new contaminants has ceased, how long will it take to reduce the air concentration to an acceptable limit? We utilize the following equation to determine the time required to reduce the concentration:

$$\ln\left(\frac{C_2}{C_1}\right) = -\frac{Q'}{V}\left(t_2 - t_1\right)$$

where

C_1 = the measured concentration
C_2 = the desired concentration
Q' = (Q/K)
K = design distribution constant (a constant factor [1–10])
Q = flow rate (cfm)
$t_2 - t_1$ = time interval or $\Delta\, t$

Example

Using the information provided in the acetone problem above, how much time would be required (assuming all sources of generation have ceased) to reduce the contamination to 50 ppm?

$$\ln\left(\frac{0.00005\,\text{ppm}}{0.000175\,\text{ppm}}\right) = -\frac{2500\,\text{cfm}}{75{,}000\,\text{ft}^2}\left(t_2 - t_1\right)$$

$$\ln 0.28 = -0.03333\left(\Delta t\right)$$

$$\frac{-1.2729}{-0.03333} = \frac{-0.03333\left(\Delta t\right)}{-0.03333}$$

$$38.2\,\text{min} = \Delta t$$

Given the information above, it will take 38.2 min to reduce the concentration of acetone from 175 to 50 ppm. *(Note*: *Remember to convert ppm to a decimal number.)*

Example

In another case, given the same information, you may be asked to determine the concentration after a given period. In order to calculate this, you will need to manipulate the equation as follows:

$$C_2 = C_1 e^{\left(-\frac{Q'\Delta t}{V}\right)} \times 10^6$$

Now, we can insert the known data to solve for the unknown, as follows:

$$C_2 = (0.000175\,\text{ppm})\, e^{\left(-\frac{2500\,\text{cfm}(60\,\text{min})}{75{,}000\,\text{ft}^3}\right)} \times 10^6$$

$$C_2 = (0.000175\,\text{ppm})\, e^{(-2)} \times 10^6$$

$$C_2 = (0.000175\,\text{ppm})(0.1353) \times 10^6$$

$$C_2 = 23.7\,\text{ppm}$$

Given the information above, the concentration of acetone after 60 min, with no additional generation of contaminant, will be 23.7 ppm.

Steady-State Concentration

The objective of dilution ventilation is to maintain a steady-state concentration, which is less than the threshold limit value (TLV) or permissible exposure limit (PEL) for the contaminant of concern. We can calculate this using the following equation:

$$Q' = \frac{G}{C}$$

where

Q' = the effective rate of ventilation corrected for incomplete mixing, cfm (Q' = **Q/K)**

K = design distribution constant to allow for incomplete mixing of contaminant air (1–10)

C = concentration of gas or vapor at time t, ppm

For example, given that Q' = 2500 cfm and G = 1.2 cfm, what is the steady-state concentration of the gas or vapor?

Inserting the known data into the equation, we have the following:

$$2500\,\text{cfm} = \frac{1.2\,\text{cfm}}{C}$$

$$\frac{2500\,\text{cfm}}{1.2\,\text{cfm}} = C$$

$$480\,\text{ppm} = C$$

Calculating Rate of Generation for Liquid Solvents

To calculate the rate of generation for liquid solvents, we utilize the following equation, which also accounts for incomplete mixing of air:

$$Q = \frac{403 \times 10^6 \times \text{SG} \times \text{ER} \times K}{\text{MW} \times C}$$

where

Q = actual ventilation rate (cfm)
SG = specific gravity of volatile liquid
ER = evaporation rate of liquid (pints/minute)
K = design distribution constant to allow for incomplete mixing of contaminant air (1–10)
MW = molecular weight of liquid
C = desired concentration of gas or vapor at time t (ppm). *Note: Normally the TLV or PEL.*

Example

Methyl ethyl ketone (MEK) is evaporating from a container at a rate of 1.2 pints every 60 min. Determine the actual ventilation rate given the following information: PEL = 200 ppm, SG = 0.81, MW = 72.11, and assume that $K = 4$.

Insert the known data into the equation as follows:

$$Q = \frac{403 \times 10^6 \times 0.81 \times \dfrac{1.2\,\text{pints}}{60\,\text{minutes}} \times 4}{72.11 \times 200\,\text{ppm}}$$

$$Q = \frac{26,114,400}{14,422}$$

$$Q = 1810.7\,\text{cfm}$$

Calculating Vapor or Gaseous Concentrations

To calculate the vapor or gaseous concentrations, we use the following equation:

$$C = \frac{P_\text{v} \times 10^6}{P_\text{b}}$$

where

C = concentration (ppm)
P_v = pressure of chemical (mm Hg)
P_b = barometric pressure (mm Hg)

Example

Given a chemical with a pressure of 350 mm Hg, what would be the concentration at a barometric pressure of 760 mm Hg?

Insert the data into the equation as follows:

$$C_{\text{ppm}} = \frac{350\,\text{mm Hg} \times 10^6}{760\,\text{mm Hg}}$$

$$C_{\text{ppm}} = \frac{3.5 \times 10^8\,\text{mm Hg}}{760\,\text{mm Hg}}$$

$$C_{\text{ppm}} = 460{,}526.3\,\text{ppm}$$

While not specifically listed on the BCSP exam reference sheet, a useful equation for calculating the concentration of vapors as a percentage is

$$C_{\text{percentage}} = \frac{P_{\text{v}} \times 100}{P_{\text{b}}}$$

Given a chemical with a vapor pressure of 350 mm Hg and a barometric pressure of 760 mm Hg, what is the concentration percentage?

$$C_{\text{percentage}} = \frac{350\,\text{mm Hg} \times 100}{760\,\text{mm Hg}}$$

$$C_{\text{percentage}} = 46.05\%$$

Calculating Room Air Changes

Determining the number of air changes in a room is done by utilizing the following equation, which is NOT listed on the BCSP examination reference sheet:

$$N_{\text{changes}} = \frac{60Q}{V_{\text{r}}}$$

where

Q = actual ventilation rate (cfm)
V_{r} = volume of room (cubic feet or ft^3)
N_{changes} = number of room air changes

Example

Given that $Q = 2500$ cfm and $V_{\text{r}} = 75{,}000\ \text{ft}^3$, calculate the number of room air changes that is occurring.

$$N_{\text{changes}} = \frac{60\,\text{min}\left(2500\,\text{cfm}\right)}{75{,}000\,\text{ft}^3}$$

$$N_{\text{changes}} = 2$$

In this example, we calculate the air to change 2 times every 60 min or 2 air changes per hour.

Calculating Concentration of a Contaminant with Dilution Ventilation

Now we will calculate the concentration of a contaminant, using air changes per hour. To do this, we will utilize the following equation:

$$C = \frac{G}{Q'}\left(1 - e^{\left(-\frac{Nt}{60}\right)}\right) \times 10^6$$

where

C = concentration at a given time (ppm)
G = rate of generation of contaminant (cfm)
Q' = (Q/K)
K = design distribution constant (a constant factor [1–10])
Q = flow rate (cfm)
t = time (in hours)

Note: The equation listed on the BCSP examination reference sheet does not multiply the product of the equation by 10^6. Therefore, it will be necessary for you to remember this correction.

Example

As the CSP, you are asked to determine the concentration of a contaminant in a storage area having a ventilation system that provides 7 air changes per 1 h. The volumetric flow rate is 2500 cfm, and the contaminant is being generated at a rate of 1.2 cfm. What is the concentration in parts per million?

$$C = \frac{1.2}{2500\,\text{cfm}}\left(1 - e^{\left(\frac{7\times1}{60}\right)}\right) \times 10^6$$

$$C = 0.00048\left(1 - 0.89\right) \times 10^6$$

$$C = 52.8\,\text{ppm}$$

Local Exhaust Ventilation

As mentioned previously in this chapter, local (exhaust) ventilation systems are designed to control contaminants at the source before mixing with breathing air occurs. They are used primarily to control the concentrations at the source of highly toxic contaminants. A local exhaust ventilation system consists of the following parts: (a) hood, (b) duct, (c) air-cleaning device, (d) fan, and (e) stack. The proper design of hoods is necessary to capture the contaminant at the source of release. The term *capture velocity* is defined as the minimum velocity of hood-induced air necessary to capture the contaminant. An example of a local exhaust ventilation system is illustrated in Photograph 9.1.

Canopy Hood

Canopy hoods are used where hot gases and vapors are encountered and workers do not work directly over the source of emissions. The major drawback to using canopy hoods is the potential for the worker to place himself or herself between the contaminant and the exhaust stream.



PHOTOGRAPH 9.1
Example of local exhaust ventilation system[2]

Down Draft Hood

Down draft ventilation is used where heavier than air contaminants exist, which are not being propelled away from the source of contaminant release. This type of ventilation system draws the air downward and away from the worker's breathing zone.

Enclosure Hood

An example of an enclosure hood is the laboratory hood. This hood actually encloses the contaminant source and the air is forced in an opposite direction (upward, downward, or backward away from the worker).

Receiving Hood

Receiving hood exhaust systems are used at the point of contaminant generation. An example of this system is a welding fume exhaust system that can be placed very close to the point of contaminant generation.

Openings

There are basically two types of hood openings. Openings can be either flanged or plain. Flanged openings have some type of "lip" on them (see Figure 9.2). Flanges are sometimes designed to create a certain desired airflow.

Plain openings do not have a flange and therefore air movement is directly into the duct. See Figure 9.3 for a diagram of a plain opening.

Calculating Hood Entry Losses

All hoods, regardless of the type, have significant energy loss, which must be accounted for. The hood entry loss represents the energy necessary to overcome the losses caused by air moving through and into the duct. Before discussing hood entry loss calculations, it is first necessary to show how to

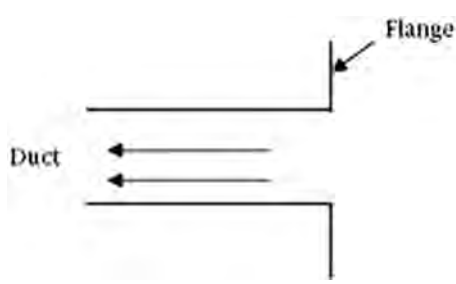


FIGURE 9.2
Flanged opening (Source: Yates, W. David 2024).

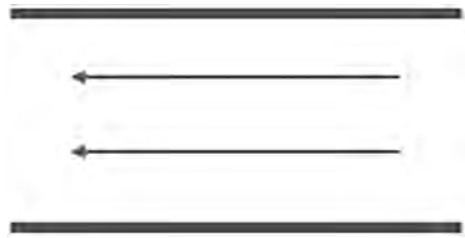


FIGURE 9.3
Plain opening (Source: Yates, W. David 2024).

calculate the coefficient of entry loss, which is the square root of the ratio of duct velocity pressure to hood static suction. This is written mathematically as follows:

$$C_e = \sqrt{\frac{\text{VP}}{\text{SP}_\text{h}}}$$

where
C_e = coefficient of entry loss
VP = velocity pressure of the duct (″wg)
SP_h = static pressure of the hood (″wg)

Theoretically, if there are no losses, then SP_h would equal to VP + C_e = 1.0. However, as we have previously mentioned, all hoods have some loss.

Example

Calculate the coefficient of entry loss given an exhaust system VP of 1.25 “wg and a static pressure of the hood of 1.82 ″wg.

$$C_e = \sqrt{\frac{1.25}{1.82}} = 0.829$$

Understanding how to calculate for the coefficient of entry loss, we can now discuss the equation for calculating the hood entry loss, which is described mathematically as follows:

$$h_e = \frac{\left(1 - C_\text{e}^2\right)\text{VP}}{C_\text{e}^2}$$

where
h_e = hood entry loss (″wg)
C_e = coefficient of entry loss
VP = velocity pressure of duct (″wg)

Example

A local exhaust system has a VP pressure of 1.37 ″wg and a C_e of 0.829. What is the hood entry loss of this system?

$$h_e = \frac{\left(1 - 0.829^2\right)1.37\,\text{″wg}}{0.829^2}$$

$$h_e = \frac{(0.3128)1.37}{0.687}$$

$$h_e = 0.624\,\text{″wg}$$

Now that we have discussed the relationship between hood entry loss, velocity pressure, and the coefficient of entry loss, we can calculate the static pressure of the hood, using the following equation:

$$\text{SP}_\text{h} = \text{VP} + h_\text{e}$$

where

SP_h = static pressure of the hood (″wg)
h_e = overall hood entry loss (″wg)
VP = duct velocity pressure (″wg)

Note: When calculating for SP_h, it is understood that the static pressure of the hood is always positive. A more accurate way of writing the equation would be as follows:

$$\left|\text{SP}_\text{h}\right| = \text{VP} + h_\text{e}$$

Example

As the safety professional, you are called upon to calculate the static pressure of the hood with the following information: VP = 0.2 ″wg and h_e = 0.1 ″wg.

Insert the data into the equation as follows:

$$\left|\text{SP}_\text{h}\right| = 0.2\,\text{″wg} + 0.1\,\text{″wg}$$

$$\left|\text{SP}_\text{h}\right| = 0.3\,\text{″wg}.$$

Calculating Airflow Velocity

Calculating airflow velocity in a local exhaust ventilation system requires that we account for the coefficient of entry loss. We can calculate the airflow

velocity and account for the coefficient of entry loss by using the following equation:

$$V = 4005C_e\sqrt{SP_h}$$

where
V = velocity of air (fpm)
C_e = coefficient of entry loss
SP_h = static pressure of the hood (″wg)

Example

Given that $C_e = 0.829$ and SP = 0.3 ″wg, what is the airflow velocity of the system?

$$V = 4005(0.829)\sqrt{0.3}$$

$$V = 3320(0.55)$$

$$V = 1826\,\text{fpm}$$

Calculating Capture Velocity for Plain Opening Hood

As mentioned in Calculating Hood Entry Losses, suction sources have contours and other imperfections that create hood entry losses, which further have an impact on capture velocities. Therefore, it is necessary to discuss the relationship between distance (from the source), the air flow, and the capture velocity. We can calculate the capture velocity using the following equation:

$$V = \frac{Q}{10X^2 + A}$$

where
V = velocity (fpm)
Q = flow rate (cfm)
X = source distance from hood opening (ft) (*Note: The equation is only accurate for a limited distance of 1.5 times the diameter of a round duct or the side of a rectangle or square duct.*)
A = area (square feet [ft^2])

Example

Calculate the capture velocity of a round duct measuring 10 in. in diameter with the contaminant source being 1.2 ft from the duct opening. The flow rate is 600 cfm.

The first step would be to determine the area of the duct, using the circle area equation.

$$A_{\text{circle}} = \pi r^2$$

$$A_{\text{circle}} = 3.14 \times 0.417^2$$

$$A_{\text{circle}} = 3.14(0.1736)$$

$$A_{\text{circle}} = 0.55\,\text{ft}^2$$

Next, we insert the known data into the equation as follows:

$$V = \frac{600\,\text{cfm}}{10(1.2\,\text{ft})^2 + (0.55\,\text{ft}^2)}$$

$$V = \frac{600\,\text{cfm}}{14.95\,\text{sq.ft}}$$

$$V = 40.13\,\text{fpm}$$

Therefore, the capture velocity under this given scenario is 40.13 fpm.

Ducts

Exhaust ducts are used to convey the contaminated air from the hood to the air cleaner or stack. When air moves through exhaust ducts, a certain amount of friction loss occurs because of the friction of the air stream with the duct. The selection of exhaust duct size is based on minimizing friction loss while maintaining an adequate transport velocity to keep particulate matter from settling out. When two or more ducts branch off from a single exhaust source, a special problem is encountered. After determining the amount of airflow required in each branch of the system, the designer must assure that the exhaust volume is properly proportioned between the two branches. This is done in one of two ways: (1) balancing the two branches by the proper sizing of ducts and fittings to assure proper distribution, or (2) blast gates, which are slide gates that can be pushed into the duct to partially block the airflow to lower the amount of air entering that branch.

One equation that is not listed on the BCSP examination reference sheet is Figure 9.4.

$$V_1A_1 = V_2A_2$$

where

V = velocity of air (fpm)
A = cross-sectional area (ft^2)

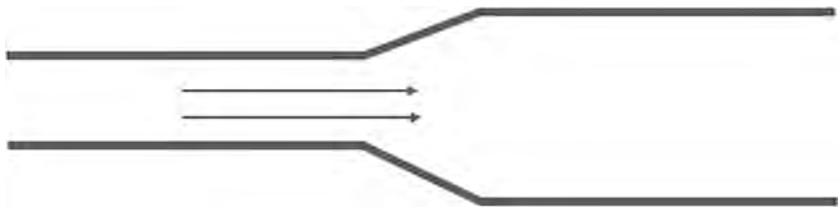


FIGURE 9.4
Duct size variations (Source: Yates, W. David 2024).

Example

A round duct has a cross-sectional area of 0.5 ft² on the first run with a velocity of 300 fpm. The duct size then increases at the second run to 0.75 ft². Determine the velocity of the second run.

$$V_1 A_1 = V_2 A_2$$

$$(300\,\text{fpm})(0.5\,\text{sq.ft}) = V_2(0.75\,\text{sq.ft})$$

$$\frac{(300\,\text{fpm})(0.5\,\text{sq.ft})}{(0.75\,\text{sq.ft})} = \frac{V_2(0.75\,\text{sq.ft})}{(0.75\,\text{sq.ft})}$$

$$200\,\text{fpm} = V_2$$

Fans

Fans generate the airflow volume (Q) of the system against airflow resistance presented by the system. In other words, they create the SP differential needed to cause the desired airflow. There are two basic types of fans: (1) axial and (2) centrifugal. Axial fans create airflow when the air enters and leaves along the axis of rotation. Centrifugal fans create airflow as the air enters along the axis of rotation and leaves perpendicularly (accelerates centrifugally) through the blades.

Calculating Static Pressure of the Fan (SP_h)

To calculate the static pressure of the fan (SP_h), we use the following equation:

$$SP_{fan} = SP_{out} - SP_{in} - VP_{in}$$

Example

Calculate the static pressure of the fan, given the following information: SP_{out} = 1.8 ″wg, SP_{in} = 0.3 ″wg, and VP_{in} = 0.4 ″wg.

$$SP_{fan} = 1.8 - 0.3 - 0.4$$

$$SP_{fan} = 1.1''wg$$

Air-Cleaning Devices

Air cleaners or air pollution devices remove contaminants from the air stream to protect the community, protect the fan, recover materials, and enable circulation.

Ventilation Measurement Equipment

There are several different types of ventilation measuring equipment. The most common types include pitot tubes, rotating vane anemometers, and thermal anemometers.

Pitot Tubes

Pitot tubes are probes that are inserted into the duct system and connected to a manometer. Pitot tubes are used to measure various pressures within the system.

Rotating Vane Anemometers

Rotating vane anemometers are used to measure airflow through large supply and exhaust systems. It is recommended that the size of the rotating vane anemometer should not exceed 5% of the cross-sectional area of the duct.

Thermal Anemometers

Thermal anemometers are primarily digital instruments that measure the heat removed by an air stream as it passes over a probe, which allows for calibration of the velocity of the air stream at a given density. The probe can be inserted directly into the air stream. This is a useful instrument, but the user should understand that errors can be created by the movement and location of the probe. It should be perpendicular to the air stream and maintained in that position until such time as the measurement is stabilized. Furthermore, the user should understand that the probe is extremely fragile; thus, precautions should be taken to protect the probe from damage.

Key Information to Remember on Ventilation

1. Pitot tubes usage is limited to velocities at or below 600–800 fpm.
2. Blast gates are used to balance the airflow in ducts of different sizes.
3. *Capture velocity* is defined as the minimum velocity of hood-induced air necessary to capture the contaminant.
4. When calculating the static pressure of the hood, remember that the SP_h is always positive.
5. Static pressure on the downstream side of the fan is positive and negative on the upstream side.
6. Backward curved fan blades are the most efficient.
7. Centrifugal fans are the best for local exhaust ventilation systems.
8. The equation for calculating capture velocities of plain hood openings is only accurate for a limited distance of 1.5 times the diameter of a round duct or the side of a rectangle or square duct.

References

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2. https://www.shutterstock.com/download/success?u=http%3A%2F%2Fdownload.shutterstock.com%2Fgatekeeper%2FW3siZSI6MTU2NjUwOTAzNCwiYyI6Il9waG90b19zZXNzaW9uX2lkIiwiZGMiOiJpZGxfMTI0ODEwNzAyOSIsImsiOiJwaG90by8xMjQ4MTA3MDI5L2h1Z2UuanBnIiwibSI6MSwiZCI6InNodXR0ZXJzdG9jay1tZWRpYSJ9LCJKSjhxbDRKU21IMG5oVGlWTWl6T0pmajJUWlUiXQ%2Fshutterstock_1248107029.jpg&pi=49239335&m=1248107029&src=y4Sbljs_vlREjM7RugKZDQ-1-7.

10

Noise and OSHA's Hearing Conservation Program

One of the most important and more common areas of concern for the occupational safety and health professional is noise and noise exposure. This chapter provides the exam candidate and the experienced professional with a basic understanding of the requirements of the hearing conservation program of the Occupational Safety and Health Administration (OSHA), along with how to correctly use the equations to determine potential noise exposures. Every equation provided on the Certified Safety Professional (CSP) exam regarding noise and hearing conservation will be discussed in detail and example problems for each will be provided.

OSHA's Hearing Conservation Program

The OSHA standard for the hearing conservation program is *29 CFR 1910.95.* This standard covers a wide variety of industries and an even wider variety of topics. The first thing that we will discuss is *Who Is Included in the Hearing Conservation Program?* It may seem easy enough to include all employees in your company in the program. However, the hearing conservation program can become very expensive, especially in the current economic hardships that some companies find themselves. OSHA requires that an employer implement a continuing hearing conservation program whenever an employee's noise exposure equals or exceeds an 8-h time-weighted average (TWA) sound level of 85 decibels (dB) on the A-scale (slow response), or equivalently a dose of 50%.[1]

Who Is Included in the Hearing Conservation Program?

As mentioned above, any employee whose noise exposure equals or exceeds an 8-h TWA sound level of 85 dB on the A-scale (slow response), or equivalently a dose of 50%, must be included in the hearing conservation program (29 CFR 1910.95). According to the OSHA standard, this noise exposure is not reduced by any noise attenuation devices (earplugs, earmuffs, or bands) and is not to be used in reducing the noise exposure for purposes of avoiding including an employee in the hearing conservation program.

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Monitoring

When information indicates that any employee's noise exposure may equal or exceed an 8-h TWA, the employer shall develop and implement a monitoring program. The sampling strategy should be designed to identify employees for inclusion in the program. For high-mobility employees, representative sampling may be used. All continuous, intermittent, and impulsive sound levels from 80 to 139 dB shall be integrated into the measurements. Instruments used to measure employee noise exposure shall be calibrated to ensure measurement accuracy. Monitoring shall be repeated whenever a change in production, process, equipment, or controls occurs.[1]

Sound Measuring Instruments

There are several types of instruments that can be used to measure an employee's sound level exposure. The *Type 1 sound level meter* is used for precision measurements in the field and has an accuracy of ±1 dB, while the *Type 2 sound level meter* is used for general purposes in the field and has an accuracy of ±2 dB. The Type 2 sound level meter is the minimum measuring device allowed for determining an employee's noise level exposure under the OSHA Hearing Conservation standard. Sound level meters can be used to spot-check employee exposures, identify potential noise sources needing further evaluation, and assist in the feasibility of engineering controls.

One of the more useful sound-measuring devices is the *octave band analyzer.* An octave band analyzer is a sound level meter that measures noise levels at various frequencies. It is useful in helping to analyze sources of noise based on frequencies, determining specific noise attenuation devices to recommend, and dividing noise into frequency components. Most octave band analyzers provide readings for 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 Hz.

The final sound measuring device that we will discuss is the *noise dosimeter.* Noise dosimeters are basically a sound level meter, but they are worn by the employee for a period (usually 8 h). The noise dosimeter computes not only the overall noise exposure but also the *dose*. Once completed, the information provided by the noise dosimeter can be printed out and placed in an employee's file.[1]

Employee Notification

OSHA requires that any employee exposed at or above an 8-h TWA of 85 dBA shall be notified of the results of the monitoring. In addition, OSHA also requires that the affected employee or their representative be provided with the opportunity to observe any noise measurements conducted.

Audiometric Testing

Under the Hearing Conservation standard, OSHA requires that audiometric testing be performed on any employee included in the program. The testing must be conducted by an audiologist, otolaryngologist, or technician certified by the Council for Accreditation in Occupational Hearing Conservation (CAOHC). The baseline audiogram must be conducted within 6 months of first exposure greater than 85 dBA, with an exception being made for companies that utilize the services of a mobile test van, which extends the requirement to a maximum of 1 year. Audiometric testing to establish the baseline audiogram shall be preceded by 14 h without exposure to excessive noise. The annual audiogram is conducted annually after the baseline. A revised baseline can be done, but only by a certified audiologist, otolaryngologist, or licensed physician. Audiometric tests must be pure tone, air conduction tests in the 500-, 1000-, 2000-, 3000-, 4000-, and 6000-Hz range; 8000 Hz is also recommended. Audiometers must meet the requirements of ANSI S3.6–1969.[1]

Standard Threshold Shift

The *Standard Threshold Shift (STS)* is a change in hearing threshold relative to the baseline audiogram of an *average* of 10 dB or more at 2000, 3000, and 4000 Hz in either ear. If an employee indicates an STS, this is recorded on the OSHA 300 log as a recordable injury. In determining whether an STS has occurred, allowance may be made for the contribution of aging *(presbycusis—natural hearing loss caused by the aging process),* using the Calculation and Application of Age Correction to Audiograms (defined in 29 CFR 1910.95 [appendix F]).

Training Program

Any employee entered into the hearing conservation program must be trained initially within 30 days of the exposure and repeated annually thereafter, as long as they are in the program. This training must include, at a minimum, the following:

- Effects of noise on hearing
- Purpose of hearing protectors (advantages, disadvantages, attenuation of various types, and instructions on selection, fitting, use, and care)
- Purpose of audiometric testing[1]

Record Keeping

Audiometric test record keeping requires the following information to be identified:

- Name and job classification of the employee
- Date of the audiogram
- Examiner's name
- Date of the last acoustic calibration
- Employee's most recent noise exposure assessment

Noise exposure measurement records are required every 2 years. Audiometric testing must be maintained in an employee's records for the duration of the employment.[1]

Noise-Related Definitions

In order to fully understand some of the items discussed in this chapter, it is necessary to understand the basic terms and their meanings.

Noise

Noise, simply defined, is unwanted sound. Sound travels in the form of waves, similar to dropping a rock in the middle of a still body of water. The waves ripple outward from the source. Noise can be harmful to humans, creating a hearing loss if uncontrolled.

Continuous Noise

Continuous noise is a sound that has unbroken sound waves of one or more different frequencies.

Intermittent Noise

Intermittent noise is a sound that has broken sound waves or is non-continuous.

Sound

Sound is *oscillations* in pressure above and below the ambient atmospheric pressure, generated by a vibrating surface or turbulent fluid flow, causing high- and low-pressure areas to be formed, which propagate away from the source. Mechanical vibrations are transmitted through an elastic medium. A sensation is produced by the stimulation of organs of hearing by vibration (AIHA,[2] p. 79).

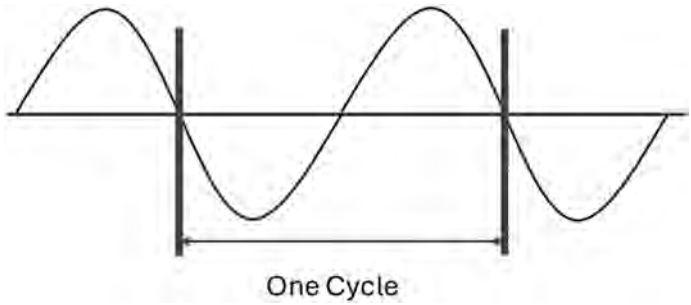


FIGURE 10.1
Illustration of One-Cycle (Source: Yates, W. David 2024).

Frequency (*f*)

Frequency is the number of complete cycles of a sound wave in 1 s. It is measured in Hertz (Hz). The normal range of hearing for human beings is 20–20,000 Hz.

Period

A *period* is the time required for one cycle. It is the reciprocal of frequency. Cycle or period is illustrated in Figure 10.1.

Speed or Velocity of Sound (*c*)

The speed or velocity of sound (*c*) is dependent upon the medium's density and compressibility. To provide examples of the speed of sound, we look at the following:

- Speed of sound in air = 332 m/s
- Speed of sound in water = 1500 m/s
- Speed of sound in steel = 6100 m/s

Speed is equal to the wavelength × frequency (cycles per second). $c = \lambda f$.

Wavelength (λ)

A wavelength is the distance traveled during one pressure cycle (Figure 10.2).

Anatomy and Physiology of the Ear

There are three major parts of the ear: the outer, middle, and inner ear. The outer ear is designed to collect sound vibrations and consists of the *pinna* (ear

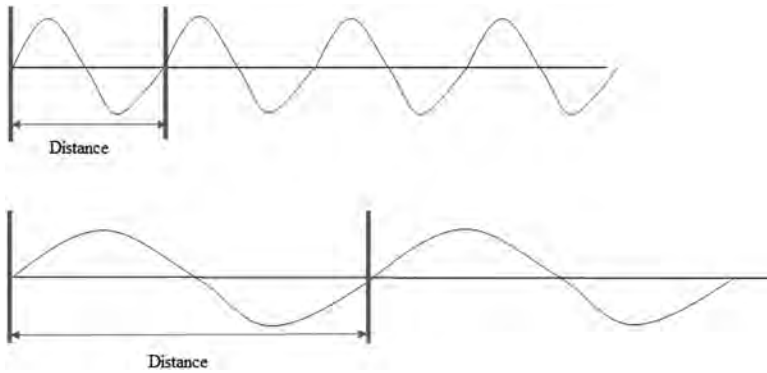


FIGURE 10.2
Diagram of a wavelength distance (Source: Yates, W. David 2024).

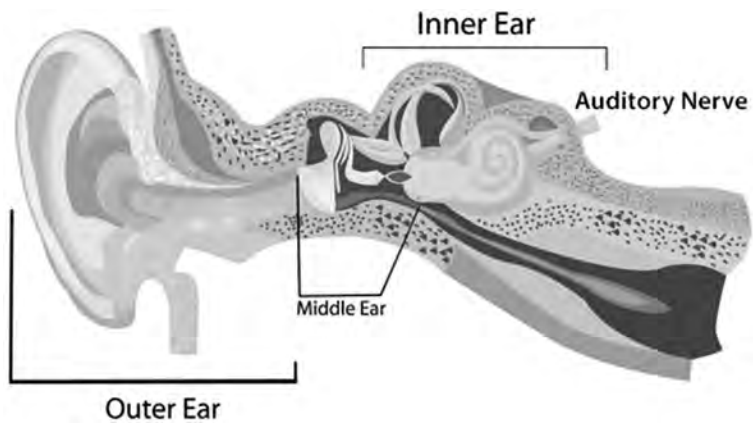


FIGURE 10.3
Anatomy of Ear[3] (Source: Centers for Disease Control, What Causes Noise-Induced Hearing Loss?, Retrieved from https://www.cdc.gov/hearing-loss/causes/?CDC_AAref_Val=https://www.cdc.gov/nceh/hearing_loss/how_does_loud_noise_cause_hearing_loss.html

lobe), which gathers sound waves and directs them toward the *external auditory canal* and onto the *tympanic membrane* (eardrum). The middle ear transmits mechanical vibrations from the air into vibrations in fluid. The middle ear consists of the *ossicles* (the *incus*, *stapes*, and *malleus* [the three smallest bones in the human body]); the *Eustachian tube*, which equalizes pressure between the middle and outer ear; the *oval window*; and the *round window.* The inner ear (also referred to as the inner transduction) changes mechanical waves in a liquid to chemical impulses sent to the brain. The inner ear consists of the *cochlea (a snail shell–shaped organ)* and the *organ of Corti,* which is the essential receptor end organ for hearing and contains the hair cells. Figure 10.2 represents the basic anatomy of the ear. Figure 10.3 illustrates the anatomy of the ear.

Types of Hearing Loss

There are basically five types of hearing loss as a result of noise-induced exposure. They are listed as follows:

Conductive—It occurs in the outer and middle ear. The loss of "loudness" only occurs. Conductive hearing loss can occur because of built-up earwax, physical obstruction of the Eustachian tube, or a perforation of the tympanic membrane.

Sensorineural—It occurs in the inner ear. As you recall, the inner ear contains the *organ of Corti,* where the "hair cells" are located. Damage to these organs is primarily irreversible. Damage as a result of hazardous or excessive noise exposure tends to occur first at the higher frequencies.

Mixed—Hearing loss can occur as a combination of both conductive and sensorineural.

Central nervous system (CNS)—Hearing loss related to the CNS occurs between the inner ear and the brain and may have many causes not related to noise exposure.

Psychogenic—It occurs in the mind. Psychogenic hearing loss may occur as a result of some type of emotional trauma.

Major Causes of Hearing Loss

- Obstruction and disease
- Acoustic trauma
- Presbycusis/sociocusis
- Noise induced

Note: Presbycusis is hearing loss as a result of the aging process, whereas sociocusis is hearing loss as a result of continuous noise exposure not related to an occupation. For example, listening to loud music continuously would be classified as sociocusis-related hearing loss.

OSHA Permissible Noise Exposures

In accordance with the OSHA Hearing standard (29 CFR 1910.95(b)(2)), an employee can be subjected to the following noise exposures for the specific times mentioned (Table 10.1).

TABLE 10.1

Permissible Noise Exposures

Exposure Times (h)	Sound Level (dbA)
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4	115

Source: United States Department of Labor, Occupational Safety and Health Administration, 29 CFR 1910.95.

It is strongly recommended that you commit Table 10.1 to memory, as there may be questions on the examination that are related to these exposure durations. In the following section, we will discuss how to calculate these times.

Entities of Noise

There are three entities of noise/sound. They are *sound power* (L_w), *sound intensity* (L_I), and *sound pressure* (L_p). Power does not change; it is constant. Intensity decreases with an increase in distance according to the inverse square law.

Sound Power (L_w)

The sound power of a source is expressed in terms of its sound power level and is written as (L_w or PWL). *Note: Commit to memory the sound power reference level, which is* 10^{-12} *W.*

Sound Pressure (L_p)

The amplitude of sound pressure disturbance can be related to the displacement amplitude of the vibrating sound source. Pressure is expressed as force per unit area. The preferred unit of pressure is the pascal (Pa) or 1 N/m^2. *Note: Commit to memory the sound pressure reference level, which is 0.00002* N/m^2.

Sound Intensity (L_I)

The sound intensity level is similar to the sound pressure level, except that intensity is a vector quantity, having both magnitude and direction (DiNardi,[2] p. 436).

Noise Calculations

As mentioned in the preface, the primary purpose of this book is to assist the exam candidate in preparing to take and successfully pass the Associate Safety Professional (ASP) and CSP exams. In the following pages, we will discuss the equations provided by the Board of Certified Safety Professionals (BCSP) on the exam reference sheet by explaining the meaning of the symbols and providing examples of their usage and examples of how to solve the equations, given a specific scenario.

Calculating Permissible Noise Exposures

As mentioned earlier in OSHA Permissible Noise Exposures, there exists an equation to help you calculate permissible exposures at various noise levels. This equation is useful whenever a noise exposure is not listed in Table 10.1. The equation is as follows:

$$T = \frac{8}{2^{\left[\left(\frac{L-90}{5}\right)\right]}}$$

For example, an employee is exposed to 80 dBA for 4 h, what is the permissible exposure time?

$$T = \frac{8}{2^{\left[\left(\frac{80-90}{5}\right)\right]}}$$

$$T = \frac{8}{2^{-2}}$$

$$T = \frac{8}{0.25}$$

$$T = 32\,\text{h}$$

In other words, using this equation, the employee could be exposed to 80 dBA for up to 32 h.

Note: The American Board of Industrial Hygiene subtracts 85 from the noise exposure in the denominator exponent.

Calculating Noise Dosage

Noise dosage is the amount of noise that an individual has been exposed to for a measured period. To calculate noise dosage, we use the following equation provided on the ASP/CSP exam reference sheet:

$$D = 100\left[\sum_{i=1}^{N} \frac{C_i}{T_i}\right]$$

where

D = dosage (or effective dose)

C_i = actual exposure time

T_i = allowed exposure time (from Table 10.1)

Given the following information, calculate the employee's total exposure to noise, expressed as a dose or percentage of PEL: 90 dB for 4 h, 92 dB for 2 h, and 80 dB for 2 h. Using the equation above, we insert the data as follows:

$$D = 100\left[\sum_{i=1}^{N} \frac{C_i}{T_i}\right]$$

$$D = 100\left[\sum_{i=1}^{N} \left(\frac{4}{8}\right) + \left(\frac{2}{6}\right) + \left(\frac{2}{32}\right)\right]$$

$$D = 100(0.89)$$

$$D = 89\%$$

To further explain, using the permissible exposure calculation in Table 10.1, we determine that an employee is permitted to be exposed to 90 dBA for 8 h, 92 dBA for 6 h, and 80 dBA for 32 h.

Another helpful equation to determine employee noise dosage exposure is

$$D = \left(\frac{C_1}{T_1}\right) + \left(\frac{C_2}{T_2}\right) \ldots \left(\frac{C_n}{T_n}\right)$$

Inserting exposures of 90 dBA for 2 h, 92 dBA for 2 h, and 95 dBA for 4 h:

$$D = \left(\frac{2}{8}\right) + \left(\frac{2}{6}\right) + \left(\frac{4}{4}\right)$$

$$D = 0.25 + 0.33 + 1$$

$$D = 1.58$$

The dosage is greater than 1, and therefore the permissible exposure limit has been exceeded. This equation is not listed on the BCSP exam reference sheet but can be quite useful in determining if exposures have been exceeded.

Converting Noise Dosage into TWA

To convert noise dosimetry readings into a TWA, we utilize the following equation:

$$\text{TWA} = 16.61 \log_{10}\left[\frac{D}{100}\right] + 90$$

where

TWA = time-weighted average

D = measured dose

Given the example that an employee has been monitored using a noise dosimeter and the results are that the employee has been exposed to 72% of the permissible exposure, what is the TWA, expressed in a sound pressure level?

$$\text{TWA} = 16.61 \log_{10}\left[\frac{72}{100}\right] + 90$$

$$\text{TWA} = 16.61 \log_{10}[0.72] + 90$$

$$\text{TWA} = (16.61)(-0.14) + 90$$

$$\text{TWA} = -2.37 + 90$$

$$\text{TWA} = 87.63 \text{ dBA}$$

Based on a noise dosimeter measurement of 72% of TWA, the TWA expressed in decibels would be 87.63 or 88 dBA.

Combining Noise Levels

Many times, especially in industrial environments, there are numerous noise sources present in the work area. An employee may have exposures from various sources with different noise levels at the same time. You cannot just add the sound level measurements and obtain an average. Hence, how do we accurately combine the noise levels? There are two methods that will be described. The first method is the decibel addition method, which utilizes Table 10.2.

To use this method, simply take the higher reading and subtract the lower reading to determine the distance. Once this is complete, add the amount to be added (corresponding difference in sound levels) to the higher reading. If combining more than two sources, calculate each combination separately. For example, there are four machines present in a facility. Machine 1 measures 79 dB, Machine 2 measures 85 dB, Machine 3 measures 90 dB, and Machine 4 measures 95 dB. What is the combined noise level?

Using Table 10.2, we perform the following steps:

Step 1: (85 dB Machine 2 *(highest reading)*—79 dB) = Difference of 6. Go to Table 10.2 and look at the corresponding addition to a difference of 6, which is 1. Therefore, we add 1 to the highest level, which is 85 + 1 = 86.

TABLE 10.2

Decibel Addition Table

Difference between Two Decibel Levels to Be Added (dB)	Amount to Be Added to a Larger Level to Obtain Decibel Sum (dB)
0	3.0
1	2.6
2	2.1
3	1.8
4	1.4
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
11	0.3
12	0.2

Note: This table is, in essence, a summary of adding logarithms.

Step 2: We take the combination measurement for Step 1 (86 dB) and determine the difference between Machine 3 (90 dB – 86 dB = 4 dB). Again, look at Table 10.2 and determine that based on a difference of 4 dB, you would add 1.4 dB. Now we add 1.4 to the highest of this combination and determine it to be 91.4 dB.

Step 3: Take the combination measurement from Step 2 (91.4 dB) and obtain the difference between this and Machine 4, which is 95 dB. The difference is 3.6 or 4. Go to Table 10.2, and you will see that you should add 1.4 to 95 dB. The final combined noise level is 96.4 dB.

As you can easily see, this method is quite time consuming, as well as cumbersome. Now we will look at the second method for determining a combination of noise levels, by using the following equation:

$$L_{\text{pt}} = 10\log\left[\sum_{i=1}^{N} 10^{\left(\frac{L_{\text{pi}}}{10}\right)}\right]$$

where

L_{pt} = combined sound pressure level

L_{pi} = individual measured sound pressure level

Using the same data as in the previous example (79, 85, 90, and 95), we insert these into the equation.

$$L_{\text{pt}} = 10\log\left[\sum_{i=1}^{N}\left(10^{\frac{79}{10}}\right)+\left(10^{\frac{85}{10}}\right)+\left(10^{\frac{90}{10}}\right)+\left(10^{\frac{95}{10}}\right)\right]$$

$$L_{\text{pt}} = 10\log\left[4,557,938,250\right]$$

$$L_{\text{pt}} = 10\left(9.659\right)$$

$$L_{\text{pt}} = 96.59\,\text{dB}$$

Calculating Sound Levels at Various Distances

From time to time, it may be necessary to calculate sound levels taken at one distance and extrapolate the sound level at another distance. To do this, we use the following equation:

$$\text{dB}_1 = \text{dB}_0 + 20\log_{10}\left(\frac{d_0}{d_1}\right),$$

where
dB_0 = the original sound level measurement
dB_1 = the calculated sound level measurement at another distance
d_0 = the original distance where noise measurement was taken
d_1 = the second distance that you would like to calculate the sound level reading for

Let's say that you have taken a sound level measurement 4 ft from a noise source and that measurement was 92 dBA. You would like to know what that noise level measurement would be at 10 ft. Inputting these data into the equation, we have

$$dB_1 = 92\,dBA + 20\log_{10}\left(\frac{4\,ft}{10\,ft}\right)$$

$$dB_1 = 92dBA + 20\log_{10}(0.4)$$

$$dB_1 = 92dBA + 20(-0.398)$$

$$dB_1 = 92 + (-7.96)$$

$$dB_1 = 84\,dB$$

If the original measurement of 92 dBA was taken at 4 ft from the source, the sound level measurement at 10 ft should be 84 dBA based on the results of this calculation.

Calculating Sound Power Level (L_w)

To calculate the sound power level, we use the following equation:

$$L_w = 10\log_{10}\frac{W}{W_0}$$

where
L_w = sound power level
W = acoustic power in watts
W_0 = reference acoustic power (10^{-12} W)

For example, you have a source that generates 0.02 W. What is the sound power level in decibels?

$$L_w = 10\log_{10}\frac{0.02}{10^{-12}}$$

$$L_w = 10\log_{10} 2\times 10^{10}$$

$$L_w = (10)(10.30)$$

$$L_w = 103\,\text{dB}$$

Calculating Sound Pressure (L_p) Levels (or SPL)

To calculate the sound pressure level, we use the following equation:

$$L_p = 20\log_{10}\frac{p}{p_o}\,\text{dB}$$

where
L_p or SPL = sound pressure level (dB)
p = measured sound pressure level (N/m^2)
p_o = reference sound pressure level (0.00002 N/m^2)

Given a measured sound pressure level of 0.002 N/m^2, what would the sound pressure level be, expressed in decibels?

Inserting the data into the equation, we have:

$$L_p = 20\log_{10}\frac{0.002}{0.00002}\,\text{dB}$$

$$L_p = 20\log_{10}100\,\text{dB}$$

$$L_p = 20(2)\,\text{dB}$$

$$L_p = 40\,\text{dB}$$

Calculating Sound Intensity Levels (L_I)

To calculate sound intensity levels, we utilize the following equation:

$$I = \frac{p^2}{\rho c}$$

Note: It must be noted that the equation on the exam reference sheet does not show the RMS sound pressure squared. Therefore, it is necessary for you to remember the correction in this equation if performing sound intensity level calculations.

where
I = sound intensity (W/m^2)
p = sound pressure level (N/m^2)
ρ = the density of the medium (in air, 1.2 kg/m^2)
c = the speed of sound (in air, it is 344 m/s)

Given a sound pressure level of 0.0796 N/m^2, calculate the sound intensity level in watts per square meter.

$$I = \frac{\left(0.0796\text{N} / \text{m}^2\right)^2}{\left(1.2\text{kg} / \text{m}^2\right)\left(344\text{m} / \text{s}\right)}$$

$$I = \frac{0.006336}{412.8}$$

$$I = 0.0000153\text{W} / \text{m}^2$$

You can insert the intensity level of 0.0000153 W/m^2 into the equation for sound power levels and determine the equivalent decibel level to be approximately 72 dB.

Calculating Room Absorption

It must be noted that the control of noise through bonding surfaces is limited in its effectiveness and can become quite costly owing to the large surface areas present. With this being said, to calculate the noise reduction from bonding surfaces, we can use the following equation:

$$\text{NR} = 10\log_{10}\frac{\left(A_2\right)}{\left(A_1\right)}$$

where
NR = noise reduction (dB)
A_1 = total number of absorption units (sabins) in the room before treatment
A_2 = total number of absorption units (sabins) in the room after treatment

Note: A sabin is a unit of sound measurement. It measures how well 1 ft^2 of any surface texture in a room is able to absorb sound reflections. A simple method for determining sabins is to multiply the square footage of surface area by the "noise reduction coefficient."

For example, you have a 20 ft × 20 ft room with hardwood flooring. You wish to install carpeting over the flooring in order to reduce sound pressure levels. What would be the overall noise reduction in decibels? (NRC [noise reduction coefficient]: hardwood, 0.15; carpeting, 0.48)

The first step would be to determine the number of square feet present, which is 400 SF. The next step would be to determine the number of sabins present before and after the installation of the carpeting. We do this by multiplying 400 SF by the NRC for each of the materials and determine that the number of sabins present before treatment is 60 and the number of sabins present after treatment is 192. Using this information, we can now solve for the noise reduction expressed in decibels.

$$\mathrm{NR} = 10\log_{10}\frac{192\,\text{sabins}}{60\,\text{sabins}}$$

$$\mathrm{NR} = 10\log_{10} 3.2$$

$$\mathrm{NR} = 10(0.505)$$

$$\mathrm{NR} = 5.05\text{dB}$$

The reduction in noise, expressed in decibels, by installing carpeting is 5 dB. As you can see, this method of controlling noise is not very effective and could become very expensive in the process.

Calculating Absorption along a Transmission Path

Normal day-to-day duties of the professional safety manager do not require him or her to calculate absorptions. However, for the purpose of preparing the candidate for the ASP/CSP exam, we will provide the equation and examples of how to use it. One of the most common examples given to show absorption along a transmission path is the commercial muffler. The equation provided on the exam reference sheet is

$$\mathrm{NR} = \frac{12.6\,P\alpha^{1.4}}{A}\,\text{dB/ft}$$

where

NR = noise reduction (decibels per foot of length)
P = perimeter of the duct (in inches)
α = absorption coefficient of the lining material at the frequency of interest
A = cross-sectional area of the duct (in inches)

By way of example, you have a duct perimeter of 5 ft (60 inches) in length with a diameter of 1 ft. The absorption coefficient for the packing material is rated at 0.54. What is the NR in decibels per foot of length?

$$\mathrm{NR} = \frac{12.6(60)\left(0.54^{1.4}\right)}{133}$$

$$NR = \frac{319.06}{113}$$

$$NR = 2.82 dB / ft$$

Key Information to Remember on Noise and the Hearing Conservation Program

1. Fourteen hours away from a noisy environment are required prior to audiometric testing.
2. OSHA's hearing conservation standard is 29 CFR 1910.95.
3. Any employee with an occupational noise exposure equaling or exceeding 85 dBA or a dose of 50% must be included in the Hearing Conservation Program.
4. The Type 2 sound level meter is the minimum standard for determining employee exposure and has an accuracy of ±1 dB.
5. Monitoring is required by 29 CFR 1910.95 every 2 years.
6. Octave band analyzers determine sound level readings at various frequencies.
7. STS is a change in hearing relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear.
8. The reference acoustic power for sound power levels is 10^{-12} W.
9. The reference sound pressure level is 0.00002 N/m^2.
10. A sabin is equal to the square footage of surface times the noise reduction coefficient.

References

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11

Biological Hazards

Biological hazards (biohazards) are substances that are biological in nature and pose a threat to the health of living organisms. Sources of biological hazards include bacteria, viruses, insects, plants, birds, animals, and humans. These sources can cause a variety of health effects ranging from skin irritation and allergies to infections (e.g., tuberculosis, AIDS), cancer, and so on. Infections from biological agents can be caused by bacteria, viruses, rickettsia, chlamydia, and fungi. Parasites include protozoa, helminths, and arthropods. Toxic and allergenic substances include bites from animals or "sticks" from plants.

Biological hazards have become a leading cause of concern in the workplace. The Occupational Safety and Health Administration (OSHA) implemented the Blood-Borne Pathogen standard (29 CFR 1910.1030) to reduce the potential for occupational illnesses related to biological hazards. Inside this chapter, we will discuss the more common biological illnesses of occupational concern and the means to prevent injuries and illnesses related to them.

Bacterial Diseases

Anthrax

The etiological agent (causative agent) for anthrax is *Bacillus anthracis.* Most forms of anthrax are lethal. The primary occupations at risk of contracting anthrax include agricultural workers and occupations handling goat hair, wool, and hides, and veterinarians. *B. anthracis* is a rod-shaped, gram-positive, aerobic bacterium. The bacterium normally rests in endospore form in the soil and can survive for decades in this state. Animals that graze on vegetation contaminated with the bacterium ingest the bacterium and become infected. Anthrax can enter the human body through ingestion, inhalation, or cutaneous routes. Normally, infected humans do not infect noninfected humans. However, the clothing and personal items of infected humans can become contaminated with the spores and cause infections in others through inhalation, ingestion, or cutaneous contamination from the spores left on these items. Preventive measures include protective, impermeable clothing and equipment; prevention of skin contact, especially open wounds; and the

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use of high-efficiency respiratory protection. Vaccines are available to aid in preventive measures, but they are only useful in the prevention of anthrax if administered well in advance of any exposure. If exposed workers are given the vaccination series, they should receive annual booster injections.

Brucellosis

Brucellosis is an infectious disease caused by bacteria of the genus *Brucella.* Occupations of interest regarding brucellosis include meatpacking house employees and inspectors, livestock producers, and marketers. These bacteria are primarily passed among animals, and they cause disease in many different vertebrates. Various *Brucella* species affect sheep, goats, cattle, deer, elk, pigs, dogs, and several other animals. Humans become infected by coming into contact with animals or animal products that are contaminated with these bacteria. In humans, brucellosis can cause a range of symptoms that are similar to the flu and may include fever, sweats, headaches, back pains, and physical weakness. Severe infections of the central nervous system or lining of the heart may occur. Brucellosis can also cause long-lasting or chronic symptoms that include recurrent fevers, joint pain, and fatigue.

Preventive measures include avoiding the consumption of unpasteurized milk, cheese, or ice cream while traveling. Hunters and animal herdsmen should use rubber gloves when handling the viscera of animals. There is no vaccine available for humans.[1]

Leptospirosis

Leptospirosis is a bacterial disease that affects humans and animals. It is caused by bacteria of the genus *Leptospira.* In humans, it causes a wide range of symptoms, and some infected persons may have no symptoms at all. Symptoms of leptospirosis include high fever, severe headache, chills, muscle aches, and vomiting, and may include jaundice (yellow skin and eyes), red eyes, abdominal pain, diarrhea, or a rash. If the disease is not treated, the patient could develop kidney damage, meningitis (inflammation of the membranes around the brain and spinal cord), liver failure, and respiratory distress. In rare cases, death occurs.[2] Occupations of special interest for leptospirosis include farmers, field workers, sugarcane workers, meatpacking house workers, sewer workers, miners, and military personnel.

The risk of acquiring leptospirosis can be greatly reduced by not swimming or wading in water that might be contaminated with animal urine. Protective clothing or footwear should be worn by those exposed to contaminated water or soil because of their job or recreational activities. Leptospirosis is treated with antibiotics, such as doxycycline or penicillin, which should be given early in the course of the disease. Intravenous antibiotics may be required for persons with more severe symptoms. Persons with symptoms suggestive of leptospirosis should contact a health care provider.[2]

Plague

The primary occupations concerned with plague include shepherds, farmers, ranchers, hunters, and geologists. Plague is an infectious disease of animals and humans caused by a bacterium named *Yersinia pestis.* People usually get plague from being bitten by a rodent flea that is carrying the plague bacterium or by handling an infected animal. Millions of people in Europe died from plague in the Middle Ages, when human homes and places of work were inhabited by flea-infested rats. Today, modern antibiotics are effective against plague, but if an infected person is not treated promptly, the disease is likely to cause illness or death.[3]

Attempts to eliminate fleas and wild rodents from the natural environment in plague-infected areas are impractical. However, controlling rodents and their fleas around places where people live, work, and play is very important in preventing human disease. Therefore, preventive measures are directed to home, work, and recreational settings where the risk of acquiring plague is high. A combined approach using the following methods is recommended:

- Environmental sanitation
- Educating the public on ways to prevent plague exposures
- Preventive antibiotic therapy[4]

Tetanus

Tetanus (also known as "lockjaw") is a serious disease that causes painful tightening of the muscles, usually all over the body. It can lead to "locking" of the jaw so the victim cannot open his mouth or swallow. It is a disease of the nervous system caused by *Clostridium tetani* bacteria, a rod-shaped, anaerobic bacterium. It is found as spores in soil or as parasites in the gastrointestinal tract of animals. Tetanus leads to death in approximately 1 in 10 cases.[5] *C. tetani* enters the body through a break in the skin. However, tetanus is not transmitted from person to person. Tetanus can be prevented using an effective vaccine. Occupations at greatest risk of contracting tetanus include those who work around domestic animals and soil.

Tuberculosis

Tuberculosis, also referred to as TB, is a disease caused by a bacterium called *Mycobacterium tuberculosis.* The bacteria usually attack the lungs, but TB bacteria can attack any part of the body, such as the kidney, spine, and brain. If not treated properly, TB disease can be fatal. TB disease was once the leading cause of death in the United States. It is spread through the air when people who have the disease cough, sneeze, or spit. Most infections in humans result

in an asymptomatic (without symptoms), latent infection, and approximately 1 in 10 latent infections eventually progress to active disease, which, if left untreated, kills more than 50% of its victims. Occupations at greatest risk include health care workers, prison employees and inmates, homeless shelter employees, and drug treatment center employees.

All healthcare settings need an infection-control program designed to ensure prompt detection, airborne precautions, and treatment of persons who have suspected or confirmed TB disease. In order to be effective, the primary emphasis of the TB infection-control program should be on achieving these three goals.[6]

In all healthcare settings, particularly those in which persons are at high risk for exposure, policies and procedures for TB control should be developed, reviewed periodically, and evaluated for effectiveness to determine the actions necessary to minimize the risk for transmission of TB.[6]

Tularemia

Tularemia is a disease of animals and humans caused by the bacterium *Francisella tularensis.* Rabbits, hares, and rodents are especially susceptible and often die in large numbers during outbreaks. Humans can become infected through several routes, including tick and deer fly bites, skin contact with infected animals, ingestion of contaminated water, or inhalation of contaminated dust or aerosols. In addition, humans could be exposed as a result of bioterrorism. Symptoms vary depending upon the route of infection. Although tularemia can be life-threatening, most infections can be treated successfully with antibiotics. Steps to prevent tularemia include the use of insect repellent, wearing gloves when handling sick or dead animals, and not mowing over dead animals. In the United States, naturally occurring infections have been reported from all states except Hawaii.[7] Primary occupations at risk include forestry workers, butchers, and meat plant operators.

Cat Scratch Fever (Cat Scratch Disease)

Cat scratch disease (CSD) is a bacterial disease caused by *Bartonella henselae.* Most people with CSD have been bitten or scratched by a cat and developed a mild infection at the point of injury. Lymph nodes, especially those around the head, neck, and upper limbs, become swollen. Additionally, a person with CSD may experience fever, headache, fatigue, and a poor appetite. Measures to reduce the risk of contracting CSD include the following:

- Avoid "rough play" with cats, especially kittens. This includes any activity that may lead to cat scratches and bites.
- Wash cat bites and scratches immediately and thoroughly with running water and soap.
- Do not allow cats to lick open wounds that you may have.

- Control fleas.
- If you develop an infection (with pus and pronounced swelling) where you were scratched or bitten by a cat or develop symptoms, including fever, headache, swollen lymph nodes, and fatigue, contact your physician.[8]

Occupations at greatest risk include animal laboratory workers, veterinarians, and animal housing employees.

Viral Diseases

Hepatitis A

Hepatitis A is an acute infectious disease of the liver caused by the hepatitis A virus (HAV). Person-to-person transmission through the fecal–oral route (i.e., ingestion of something that has been contaminated with the feces of an infected person) is the primary means of HAV transmission in the United States. Most infections result from close personal contact with an infected household member or sex partner. Common-source outbreaks and sporadic cases can also occur from exposure to fecally contaminated food or water. Uncooked HAV-contaminated foods have been recognized as a source of outbreaks. Cooked foods can also transmit HAV if the temperature during food preparation is inadequate to kill the virus or if food is contaminated after cooking, as occurs in outbreaks associated with infected food handlers. Waterborne outbreaks are infrequent in developed countries with well-maintained sanitation and water supplies.[9] Occupations with the greatest potential exposure include daycare center workers, food preparation workers, and sewer and sanitation workers.

Vaccination with the full, two-dose series of hepatitis A vaccine is the best way to prevent HAV infection. The hepatitis A vaccine has been licensed in the United States for use in persons 12 months of age and older. The vaccine is recommended for persons who are more likely to get HAV infection or are more likely to get seriously ill if they get hepatitis A.[9]

Hepatitis B

Hepatitis B is caused by infection with the hepatitis B virus (HBV). The incubation period from the time of exposure to the onset of symptoms is 6 weeks to 6 months. HBV is found in the highest concentrations in blood and in lower concentrations in other body fluids (e.g., semen, vaginal secretions, and wound exudates). HBV infection can be self-limited or chronic.

HBV is efficiently transmitted by percutaneous or mucous membrane exposure to infectious blood or body fluids that contain blood. The primary

risk factors that have been associated with infection are unprotected sex with an infected partner, birth to an infected mother, unprotected sex with more than one partner, men who have sex with other men (MSM), history of other sexually transmitted diseases (STDs), and illegal injection drug use.

The national strategy of the Centers for Disease Control and Prevention (CDC) to eliminate transmission of HBV infection includes

- Prevention of perinatal infection through routine screening of all pregnant women for HBsAg and immunoprophylaxis of infants born to HBsAg-positive mothers and infants born to mothers with unknown HBsAg status
- Routine infant vaccination
- Vaccination of previously unvaccinated children and adolescents through age 18 years
- Vaccination of previously unvaccinated adults at increased risk for infection

High vaccination coverage rates, with subsequent declines in acute hepatitis B incidence, have been achieved among infants and adolescents. In contrast, vaccination coverage among the majority of high-risk adult groups (e.g., persons with more than one sex partner in the previous 6 months, MSM, and injection drug users) has remained low, and the majority of new infections occur in these high-risk groups. STD clinics and other settings that provide services targeted to high-risk adults are ideal sites in which to provide hepatitis B vaccination to adults at risk for HBV infection. All unvaccinated adults seeking services in these settings should be assumed to be at risk for hepatitis B and should receive hepatitis B vaccination.[10] In addition, those employees working in the health care industry or emergency medicine pose the greatest occupational exposures.

Orf (Sore Mouth Disease)

Sore mouth is caused by a poxvirus (specifically orf virus) and is found all over the world. The scabs of infected animals contain the virus, can fall off, remain in the environment, and serve as a source of infection to susceptible animals. A flock can become infected through contaminated bedding, feed, or trucks, or by direct contact with infected animals (e.g., replacements brought onto the operation or at shows).[11]

People can become infected with the virus that causes sore mouth. A person who comes into contact with the virus from an infected animal or equipment (such as a harness that has rubbed the animal's sores) can potentially get infected. People often develop sores on their hands. The sores may be painful and can last for 2 months. People do not infect other people. Sores usually heal without scarring.[11]

The virus that causes sore mouth is spread to people by touching infected animals and their equipment. Some animals may or may not have visible sores but may still be able to spread the virus.[11]

The two ways to protect yourself and others include:

1. Wear nonporous (i.e., rubber or latex) gloves when handling sheep or goats, especially when you have an open cut or sore and are handling the animals' mouth/muzzle area.
2. Practicing good hand hygiene by washing with clean, warm water and soap for at least 20 s (or using a waterless alcohol-based hand rub when soap is not available and hands are not visibly soiled).[11]

Occupations at greatest risk of exposure include shepherds, stockyard workers, and shearers (sheep and goats).

Rabies

Rabies is a preventable viral disease of mammals most often transmitted through the bite of a rabid animal. The vast majority of rabies cases reported to the CDC each year occur in wild animals like raccoons, skunks, bats, and foxes.[12]

The rabies virus infects the central nervous system, ultimately causing disease in the brain and death. The early symptoms of rabies in people are similar to those of many other illnesses, including fever, headache, and general weakness or discomfort. As the disease progresses, more specific symptoms appear and may include insomnia, anxiety, confusion, slight or partial paralysis, excitation, hallucinations, agitation, hypersalivation (increase in saliva), difficulty swallowing, and hydrophobia (fear of water). Death usually occurs within days of the onset of these symptoms.[12]

All species of mammals are susceptible to rabies virus infection, but only a few species are important as reservoirs for the disease. In the United States, distinct strains of the rabies virus have been identified in raccoons, skunks, foxes, and coyotes. Several species of insectivorous bats are also reservoirs for strains of the rabies virus.[12]

Transmission of rabies virus usually begins when infected saliva of a host is passed to an uninfected animal. The most common mode of rabies virus transmission is through the bite and virus-containing saliva of an infected host, although transmission has been rarely documented via other routes such as contamination of mucous membranes (i.e., eyes, nose, and mouth), aerosol transmission, and corneal and organ transplantations.[12]

For people who have never been vaccinated against rabies previously, postexposure anti-rabies vaccination should always include administration of both passive antibody and vaccine.

The combination of human rabies immune globulin and vaccine is recommended for both bite and nonbite exposures, regardless of the interval between exposure and initiation of treatment.[12]

People who have been previously vaccinated or are receiving preexposure vaccination for rabies should receive only the vaccine.[12] Occupations at greatest risk include veterinarians, wild animal handlers, cave explorers, and farmers and ranchers.

Rickettsial and Chlamydia Diseases

Psittacosis (Ornithosis)

Psittacosis is a zoonotic infectious disease caused by a bacterium called *Chlamydophila psittaci* and contracted not only from parrots, such as macaws, cockatiels, and budgerigars, but also from pigeons, sparrows, ducks, hens, gulls, and many other species of birds. Infection is acquired by inhaling dried secretions from infected birds. The incubation period is 5–19 days. Although all birds are susceptible, pet birds (parrots, parakeets, macaws, and cockatiels) and poultry (turkeys and ducks) are most frequently involved in transmission to humans. Bird owners, pet shop employees, and veterinarians are among the highest occupations at risk. Outbreaks of psittacosis in poultry processing plants have been reported.[13]

Preventive measures include continued education, and when handling potentially infected birds, such as cleaning of the cages, employees should wear the appropriate protective equipment, which includes the wearing of an N95 respirator or a higher level of protection. According to the National Association of State Veterinarians, Inc., surgical masks may not be effective in preventing the transmission of this disease.

Rocky Mountain Spotted Fever

Rocky Mountain spotted fever is the most severe tick-borne rickettsial illness in the United States. Occupations at greatest risk include military personnel, foresters, rangers, ranchers, farmers, trappers, construction workers, and lumber workers. This disease is caused by infection with the bacterial organism *Rickettsia rickettsii.* The organism that causes Rocky Mountain spotted fever is transmitted by the bite of an infected tick. The American dog tick (*Dermacentor variabilis)* and Rocky Mountain wood tick (*Dermacentor andersoni*) are the primary arthropods (vectors) that transmit Rocky Mountain spotted fever bacteria in the United States. The brown dog tick (*Rhipicephalus sanguineus*) has also been implicated as a vector as well as the tick *Amblyomma cajennense* in countries south of the United States.[14]

It is unreasonable to assume that a person can completely eliminate activities that may result in tick exposure. Therefore, take the following precautions to protect yourself when exposed to natural areas where ticks are present:

- Wear light-colored clothing that allows you to see ticks that are crawling on your clothing. Tuck your pant legs into your socks so that ticks cannot crawl up the inside of your pant legs.
- Apply repellents to discourage tick attachment. Repellents containing permethrin can be sprayed on boots and clothing and will last for several days. Repellents containing DEET (*N*,*N*-diethyl-*m*-toluamide) can be applied to the skin but will last only a few hours before reapplication is necessary. Use DEET with caution on children.
- Conduct a body check upon returning from potentially tick-infested areas by searching your entire body for ticks. Use a handheld or full-length mirror to view all parts of your body. Remove any tick you find on your body.

Check children for ticks, especially in the hair, when returning from potentially tick-infested areas. Ticks may also be carried into the household on clothing and pets and may only attach later, so both should be examined carefully to exclude ticks.[15]

Q Fever

Q fever is a zoonotic disease caused by *Coxiella burnetii*, a species of bacteria that is distributed globally. Occupations at greatest risk include veterinarians, dairy farmers, ranchers, stockyard workers, slaughterhouse employees, wool handlers, and rendering plant workers. In 1999, Q fever became a notifiable disease in the United States, but reporting is not required in many other countries. Because the disease is underreported, scientists cannot reliably assess how many cases of Q fever have occurred worldwide. Many human infections are inapparent.[16]

Cattle, sheep, and goats are the primary reservoirs of *C. burnetii*. Infection has been noted in a wide variety of other animals, including other species of livestock and in domesticated pets. *C. burnetii* does not usually cause clinical disease in these animals, although abortion in goats and sheep has been linked to *C. burnetii* infection. Organisms are excreted in the milk, urine, and feces of infected animals. Most importantly, during birthing, the organisms are shed in high numbers within the amniotic fluids and the placenta. The organisms are resistant to heat, drying, and many common disinfectants. These features enable the bacteria to survive for long periods in the environment. Infection of humans usually occurs by inhalation of these organisms from air that contains airborne barnyard dust contaminated by dried placental material, birth fluids, and excreta of infected herd animals. Humans are often very susceptible to the disease, and very few organisms may be required to cause infection.[16]

Ingestion of contaminated milk, followed by regurgitation and inspiration of the contaminated food, is a less common mode of transmission. Other modes of transmission to humans, including tick bites and human-to-human transmission, are rare.[16]

The following measures should be used in the prevention and control of Q fever:

- Educate the public on sources of infection.
- Appropriately dispose of placentas, birth products, fetal membranes, and aborted fetuses at facilities housing sheep and goats.
- Restrict access to barns and laboratories used for housing potentially infected animals.
- Use only pasteurized milk and milk products.
- Use appropriate procedures for bagging, autoclaving, and washing laboratory clothing.
- Vaccinate (where possible) individuals engaged in research with pregnant sheep or live *C. burnetii.*
- Quarantine imported animals.
- Ensure that holding facilities for sheep are located away from populated areas. Animals should be routinely tested for antibodies to *C. burnetii,* and measures should be implemented to prevent airflow to other occupied areas.
- Counsel persons at highest risk for developing chronic Q fever, especially those with preexisting cardiac valvular disease or individuals with vascular grafts.

A vaccine for Q fever has been developed and has successfully protected humans in occupational settings in Australia. However, this vaccine is not commercially available in the United States.[16]

Fungal Diseases

Aspergillosis

Aspergillus is a fungus (or mold) that is very common in the environment. It is found in soil, on plants, and in decaying plant matter. It is also found in household dust, building materials, and even in spices and some food items. There are lots of different types of *Aspergillus,* but the most common ones are *Aspergillus fumigatus* and *Aspergillus flavus.* Some others are *Aspergillus terreus, Aspergillus nidulans,* and *Aspergillus niger.*[17]

Aspergillosis is a disease caused by *Aspergillus.* Farmers and grain workers are the primary occupations of concern regarding aspergillosis. There are many different kinds of aspergillosis. One kind is allergic bronchopulmonary aspergillosis (also called ABPA), a condition where the fungus causes allergic respiratory symptoms, such as wheezing and coughing, but does

not actually invade and destroy tissue. Another kind of aspergillosis is invasive aspergillosis, a disease that usually affects people with immune system problems. In this condition, the fungus invades and damages tissues in the body. Invasive aspergillosis most commonly affects the lungs but can also cause infection in many other organs and can spread throughout the body.[17]

Since *Aspergillus* is so common in the environment, most people breathe in *Aspergillus* spores every day. It is probably impossible to completely avoid breathing in some *Aspergillus* spores. For people with healthy immune systems, this does not cause harm, and the immune system is able to get rid of the spores. But for people with compromised immune systems, breathing in *Aspergillus* spores, especially breathing in a lot of spores (such as in a very dusty environment), can lead to infection. Studies have shown that invasive aspergillosis can occur during building renovation or construction. Outbreaks of *Aspergillus* skin infections have been traced to contaminated biomedical devices.[17]

It is almost impossible to avoid all exposure to this fungus. It is present in the environment. However, for persons who are very immunocompromised, some measures that may be helpful include avoiding dusty environments and activities where dust exposure is likely (such as construction zones), wearing N95 respirators when traveling near dusty environments, and avoiding activities such as gardening and lawn work. Other air quality improvement measures, such as HEPA filtration, may be used in healthcare settings, and prophylactic antifungal medication may, in some circumstances, be prescribed by your doctor.[17]

Candidiasis

Candidiasis is also known as *thrush* and is a fungal infection of the *Candida* species, with *Candida albicans* being the most common. Occupations at greatest risk include dishwashers, bartenders, cooks, bakers, poultry, and packinghouse workers. Candidiasis is usually localized as infections of the skin or mucosal membranes of the oral cavity (thrush), the pharynx or esophagus, the gastrointestinal tract, the urinary bladder, or the genitalia. This disease can be transmitted sexually through intercourse. Prevention includes frequent handwashing and avoidance of hand-to-mouth or hand-to-genitalia contact when handling contaminated items.

Coccidiomycosis

Coccidiomycosis, also known as Valley Fever, is a fungal disease caused by *Coccidioides* species. These organisms live in the soil of semiarid areas. It is endemic in areas such as the southwestern United States, parts of Mexico, and South America. It is a reportable disease in states where the disease is endemic, such as California, New Mexico, Arizona, and Nevada. Of people who live in an endemic region, approximately 10%–50% will have evidence

of exposure to *Coccidioides.* Most of the people who get the disease are people who live in or visit places where the fungus is in the soil and engage in activities that expose them to dust (such as construction, agricultural work, military field training, and archeological exploration). The infection is not spread from person to person or from animals to people. The infectious form of the fungus exists when the fungus grows in the environment. The fungus changes its form when it infects a person, and this form cannot be transmitted from one person to another. Avoidance of dusty environments in endemic regions may help prevent infection. In addition, persons at risk for severe disease should avoid activities that may result in dust exposure, such as digging.[18]

Histoplasmosis

Histoplasmosis is a disease caused by the fungus *Histoplasma capsulatum.* Its symptoms vary greatly, but the disease primarily affects the lungs. Occasionally, other organs are affected. This form of the disease is called disseminated histoplasmosis, and it can be fatal if untreated. Occupations at greatest risk include environmental remediation workers, farmers, poultry workers, and veterinarians. *H. capsulatum* grows in soil and material contaminated with bat or bird droppings. Spores become airborne when contaminated soil is disturbed. Breathing the spores causes infection. The disease is not transmitted from an infected person to someone else.

It is not practical to test or decontaminate most sites that may be contaminated with *H. capsulatum,* but the following precautions can be taken to reduce a person's risk of exposure:

- Avoid areas that may harbor the fungus, for example, accumulations of bird or bat droppings.
- Before starting a job or activity with a risk for exposure to *H. capsulatum,* consult the NIOSH/NCID document *Histoplasmosis: Protecting Workers at Risk.* This document contains information on work practices and personal protective equipment that will reduce the risk of infection. A copy of this document can be obtained by requesting publication no. 2005-109 from the National Institute for Occupational Safety and Health. You can also request additional information by calling 1-800-CDC-INFO.[19]

Biological Safety

The primary objective of any biological safety program is to contain any harmful or potentially harmful biological agents inside a controlled environment. The purpose of *primary containment* is to protect personnel and the

immediate laboratory environment from exposure to infectious agents. The purpose of *secondary containment* is the protection of the environment outside of the laboratory. There are three basic elements to a containment program: laboratory practice and technique, safety equipment, and facility design. Each of these will be discussed in this chapter.

Laboratory Practice and Technique

Any laboratory working with hazardous or potentially hazardous agents should develop standard operating procedures in place prior to handling any hazardous agents. The procedures and practices should be strictly enforced at all times to prevent contamination or exposure. Employees working with these agents should be thoroughly trained and knowledgeable of these procedures, including emergency action plans. This training should be carefully reviewed and updated periodically to ensure that the employees are protected. Whenever there are new procedures or new agents introduced into the laboratory, retraining should be conducted.

Some of the standard laboratory practices included in the operating manual should address the following:

- Limited and controlled access to the laboratory.
- Work areas, particularly horizontal surfaces, should be cleaned and decontaminated daily.
- Contaminated materials, including cleaning materials, should be decontaminated prior to disposal.
- Eating, drinking, smoking, or gum chewing should be strictly prohibited inside the controlled area.
- Frequent handwashing should be enforced.
- Protective clothing should be worn to prevent the contamination of street clothes.
- Depending on the agents inside the laboratory, showering of employees inside a decontamination station may be required.
- Training.

Safety Equipment

Specific safety equipment for each laboratory will be different. However, the basic safety equipment includes biological safety cabinets, personal protective equipment, and safety centrifuge cups. Biological safety cabinets are

classified as Class I, Class II, or Class III. Class I cabinets are considered partial containment cabinets and have the following features:

- Room air flows through a fixed front opening.
- Approximately 8 in.
- Minimum velocity of 75 linear fpm.
- Prevents aerosols generated in the cabinet from escaping into the room.
- Not appropriate for experimental systems vulnerable to airborne contamination.

Class II cabinets are laminar flow cabinets and have the following features:

- Protect the worker and research material.
- Curtain of room air entering the grille at the forward edge of the opening to the work surface.
- Partial recirculation of HEPA-filtered air.
- Downward flow of HEPA-filtered air creates a contaminant-free zone.

Class II, Type A

- Fixed work opening.
- Minimum inflow velocity of 75 linear fpm.
- 70% of recirculation.
- Minimum vertical velocity of 75 linear fpm.
- Not for flammable solvents, toxic agents, or radioactive materials.

Class II, Type B1

- Vertical sliding sash.
- 100 linear fpm at 8-in. work opening.
- 50 linear fpm of downward vertical air velocity.
- 70% of the air flowing through the work area is exhausted.
- Not recommended for explosive vapors.

Class II, Type B2

- HEPA downflow air is from laboratory or outside air.
- Minimum inflow velocity of 100 fpm.

- 100% exhaust to outside through HEPA; no recirculation within the cabinet.
- Used for low- to moderate-risk biological agents, toxic chemicals, and radionuclides.

Class II, Type B3

- HEPA downflow air is from laboratory or outside air.
- Minimum inflow velocity of 100 fpm.
- 70% of recirculated air is exhausted to the outside through HEPA.
- Used for low- to moderate-risk biological agents, minute or trace amounts of toxic chemicals, and radionuclides.

Class III (gas tight, negative pressure)

- Provides a physical barrier between the agent and worker.
- Highest degree of worker protection.
- Arm-length rubber gloves and a sealed front panel.
- Air is drawn into cabinet through HEPA filtration.[20]

Facility Design and Construction

Facility design and construction serve as secondary barriers. That is, the primary purpose is to prevent the escape of hazardous materials or agents outside of the controlled environment. Obviously, the design and construction of the laboratory will depend primarily on the nature and potential hazards of the agent.

Biosafety Levels

The level of safety when working with biological agents depends primarily on the potential hazards presented by the specific agent. In this section, we will discuss the four levels of biosafety. When discussing the biosafety levels, keep in mind the three major areas of containment, laboratory practices and techniques, and safety equipment and facility design.

Biosafety Level I

This level represents the basic level of containment and relies on standard microbiological practices. There are no special primary or secondary barriers

required, except for handwashing facilities. This level is appropriate for any undergraduate or secondary educational training laboratory.

Biosafety Level II

Practices and techniques for biosafety level II include the use of standard microbiological techniques, training of personnel, collection of baseline serum samples taken and stored, warning signage, and personal protective equipment. Equipment for biosafety level II includes Class I or Class II biological safety cabinets. Access to the laboratory should be limited, and decontamination of equipment and instruments is required. This level of biosafety is adequate for most medical laboratories.

Biosafety Level III

With biosafety level III, greater emphasis is placed on primary and secondary barriers. Practices and techniques include performing all manipulations of agents in a biological safety cabinet or other enclosed equipment, such as a gas-tight aerosol generation chamber, and strict controlled access to the laboratory environment. The use of biological cabinets (Class I, II, or III) and personal protective equipment should be strictly enforced. This level of safety is adequate for laboratories that perform work on indigenous or exotic agents with a potential for respiratory transmission that may cause serious and potentially lethal infection.

Biosafety Level IV

Biosafety level IV is the highest level of protection. Practices and techniques to prevent infection or escape of hazardous agents include all manipulations being performed in biological cabinets, sealing openings to the laboratory, standard microbiological practices, warning signage, and frequent handwashing. Safety equipment includes biological safety cabinets (Class I, II, or III), and depending on the hazardous agent, special engineering may be required. An airlock between the laboratory and public areas should be installed to prevent the escape of the hazardous agent.

Key Information to Remember on Biological Hazards

1. OSHA's Blood-Borne Pathogen Standard is found in 29 CFR 1910.1030.
2. The etiological agent for anthrax is *B. anthracis.*
3. Plague is an infectious disease of animals and humans caused by a bacterium named *Y. pestis.*

4. Tetanus, also known as "lockjaw," is a disease of the nervous system caused by *C. tetani.*
5. The bacterium *M. tuberculosis* causes tuberculosis.
6. Person-to-person transmission through the fecal-oral route is the primary means of HAV spread in the United States.
7. Hepatitis B can be transmitted by percutaneous or mucous membrane exposure to infectious blood or body fluids that contain blood.
8. *Aspergillus* is a fungus (mold) that can cause aspergillosis in farmers and grain workers.
9. Three primary preventive measures in biological safety include laboratory practice and techniques, safety equipment, and facility construction and design.
10. There are four levels of biosafety (Levels I, II, III, and IV).

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12

Fire Prevention and Protection

An area of major concern for today's safety professionals is the prevention of fires and the protection of personnel and property from the effects of fires. To fully understand the preventive measures to be taken, you must first understand the causes of fires. We begin this chapter by discussing the terminology that will be used.

Definitions

Combustion: Combustion is a chemical reaction that occurs between a fuel and an oxidizing agent that produces energy, usually in the form of heat and light. When a fuel is burned, the carbon reacts with the oxygen and can form either carbon monoxide (CO) or carbon dioxide (CO_2).

Heat of combustion: The amount of heat in calories evolved by the combustion of 1 g weight of a substance.

Combustible liquid: Any liquid having a flash point at or above 140°F and below 200°F.

Flammable liquid: Any liquid having a flash point below 140°F and having a vapor pressure not exceeding 40 psia at 100°F.

Flash point: The minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid. The flash point is normally an indication of susceptibility to ignition.

Lower flammability limit: The lower end of the concentration range of a flammable solvent at a given temperature and pressure for which air/vapor mixtures can ignite. The lower flammability limit (LFL) is usually expressed in volume percent.

Upper flammability limit: The maximum concentration of a combustible substance capable of propagating a flame through a homogeneous combustible mixture. The upper flammability limit (UFL) is usually expressed in volume percent.

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Transfer of Heat

In this section, we will discuss three primary methods of heat transfer, which include (1) radiation, (2) convection, and (3) conduction. It is important to understand the process of heat transfer. Heat always moves from a warmer place to a cooler place. Hot objects in a cooler room will eventually cool to room temperature. Cold objects in a warmer room will heat up to room temperature.

Heat Transfer by Radiation

Radiation heat is the amount of thermal radiation between two or more objects (bodies). Radiation travels in wavelengths and does not require that the two objects be in contact, as radiation can travel through a vacuum or space. We can calculate the radiation heat transfer rate by using the following equation:

$$\frac{Q}{A} = \varepsilon\sigma T^4$$

where
- Q/A = heat flux (energy/time area)
- A = area of heat transfer
- ε = emissivity of radiating body
- σ = Stefan–Boltzmann constant
- T = absolute temperature

Heat Transfer by Convection

Convection can be defined as the process whereby thermal energy is transferred by the movement of a heated fluid such as liquid or air. There can be natural convection and forced convection. The rate of convective heat transfer can be calculated as follows:

$$Q = hA\left(T_s - T_b\right)$$

where
Q = convective heat transfer rate
h = heat transfer coefficient
A = surface area of the heat being transferred
T_s = surface temperature
T_b = temperature of the fluid at bulk temperature

Heat Transfer by Conduction

Conduction is the transfer of thermal energy between two objects in contact with each other. The conductive heat transfer rate is calculated as follows:

$$Q = kA\left(\frac{T_1 - T_2}{L}\right)$$

where
Q = conductive heat transfer rate
k = thermal conductivity constant of material
A = surface area
T_1 = temperature on one side of a surface
T_2 = temperature on the opposite side of a surface
L = thickness of a material (distance of one side to the opposite side of a material)

Fire Tetrahedron

There are four components that are necessary to sustain combustion. Without the presence of all four components, fires will not exist. The four components include fuel, oxygen, heat, and a chain reaction. The fire tetrahedron is illustrated in Figure 12.1.

Understanding the fire tetrahedron is important not only in determining how to extinguish fires but also in preventing them from occurring. Fuels are present everywhere and can include solids, liquids, gases, or vapors. The type of fuel in a fire will determine the type of extinguishing media that must be used.

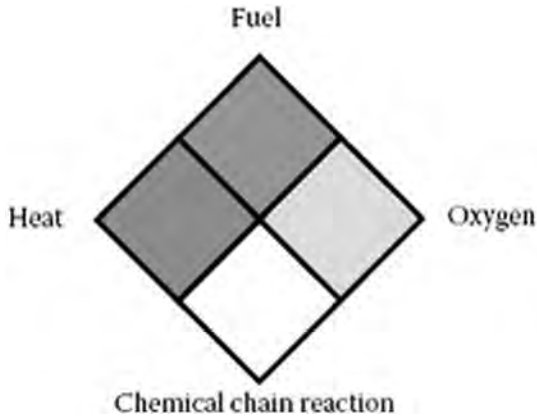


FIGURE 12.1
Fire tetrahedron (Source: Yates, W. David 2024).

Classification of Fires

According to the National Fire Protection Association (NFPA), fires can be classified as A, B, C, D, or K.

Class A Fires

Class A fires involve common combustibles such as wood, paper, cloth, rubber, trash, and plastics. They are common in typical commercial and home settings but can occur anywhere these types of materials are found.

Class B Fires

Class B fires involve flammable liquids, gases, solvents, oil, gasoline, paint, lacquers, tars, and other synthetic or oil-based products. Class B fires often spread rapidly and, unless properly secured, can reflash after the flames are extinguished.

Class C Fires

Class C fires involve energized electrical equipment, such as wiring, controls, motors, data processing panels, or appliances. They can be caused by a spark, power surge, or short circuit and typically occur in locations that are difficult to reach and see.

Class D Fires

Class D fires involve combustible metals such as magnesium and sodium. Combustible metal fires are unique industrial hazards that require special dry powder agents to extinguish.

Class K Fires

Class K fires involve combustible cooking media such as oils and grease commonly found in commercial kitchens. The new cooking media formulations used for commercial food preparation require a special wet chemical extinguishing agent that is especially suited for extinguishing and suppressing these extremely hot fires, which have the ability to reflash.

Portable Fire Extinguishers

It is important to understand the classification of fires when selecting the appropriate type of fire extinguisher. For example, water should not be used to put out a Class C (electrical) fire, since it presents a shock hazard. Fire extinguishers are labeled in such a manner as to clearly identify the class of fires that they can extinguish. The new labeling system for fire extinguishers uses pictures to indicate what types of fires extinguishers can be used on and red diagonal lines through the types of fires they should not be used on. Figure 10.2 shows the symbols of the new labeling system.

In addition, fire extinguishers also come with number ratings to indicate how large a fire they can contain. For example, Class A extinguishers may have a numeric rating of 1, which would indicate 1 gal of extinguishing material. A higher rating number indicates increased levels of firefighting protection in each progressive extinguisher. The number ratings on Class B or C fire extinguishers indicate how many square feet of coverage the unit will contain. For example, a numeric rating of 5BC indicates a 5 ft^2 of coverage area for Class B and C fires. A multipurpose fire extinguisher may be rated at (example) 2A–10BC, which means that the extinguisher will cover up to 3000 ft^2 for Class A fires and 10 ft^2 for B/C fires. Table 12.1 shows the hazard level, minimum fire extinguisher rating required, maximum travel distance to a fire extinguisher, and the maximum square footage of Figure 12.2 scoverage.[1]

Hydrostatic Testing (Portable Fire Extinguishers)

The Occupational Safety and Health Administration (OSHA) requires that portable fire extinguishers undergo hydrostatic testing at intervals listed in Table 12.2, except under the following circumstances:

TABLE 12.1

Portable Fire Extinguishers and Travel Distances by Hazard

Hazard Level	Minimum Fire Extinguisher Rating	Maximum Travel Distance to a Fire Extinguisher	Maximum Square Footage
Light hazard	2A10B:C	75 ft	Maximum coverage of 3000 ft^2 per unit of A (2A can cover 6000 ft^2)
Ordinary hazard with moderate amounts of Class A combustibles and only minimal amounts of flammable/ combustible liquids and gases	2A10B:C	75 ft	Maximum coverage of 1500 ft^2 per unit of A (2A extinguisher in this case can cover 3000 ft^2)
Ordinary hazard with moderate amounts of flammable/ combustible liquids and gases	Option 1 2A10B:C	30 ft	Maximum coverage of 1500 ft^2 per unit of A (2A extinguisher can cover 3000 ft^2)
	Option 2 2A20B:C	50 ft	Maximum coverage of 1500 ft^2 per unit of A (2A extinguisher can cover 3000 ft^2)
Extra hazard—all types	Option 1 4A40B:C	30 ft	Maximum coverage of 1000 ft^2 per unit of A (4A extinguisher can cover 4000 ft^2)
	Option 2 4A80B:C	50 ft	Maximum coverage of 1000 ft^2 per unit of A (4A extinguisher can cover 4000 ft^2)
Commercial kitchens	2A1B:C;K	30 ft	Maximum coverage of 1000 ft^2 per unit of A (2A extinguisher can cover 2000 ft^2)

Source: Livermore-Pleasanton Fire Department, Livermore, California, http://www.ci.livermore.ca.us/LPFD/pdfs/fpfireextgl.pdf.

- When the unit has been repaired by soldering, welding, brazing, or the use of patching compounds
- When the cylinder or shell threads are damaged
- When there is corrosion that has caused pitting, including corrosion under removable name plate assemblies
- When the extinguisher has been burnt in a fire
- When a calcium chloride extinguishant agent has been used in a stainless-steel shell



FIGURE 12.2
Fire extinguisher symbols (new labeling system) (Source: https://www.shutterstock.com/image-vector/fire-class-types-extinguisher-poster-flammable-2206280627/edit?tool=bgremover&chatId=1be600b74d5d4cfead4f3d3628a8c724).

TABLE 12.2

OSHA's Hydrostatic Test Intervals (OSHA 29 CFR 1910.157(f)(3) Table L-1)

Type of Extinguisher	Test Interval (years)
Soda acid (soldered brass shells) (until January 1, 1982)	[a]
Soda acid (stainless steel shell)	5
Cartridge operated water and/or antifreeze	5
Stored pressure water and/or antifreeze	5
Wetting agent	5
Foam (soldered brass shells) (until January 1, 1982)	[a]
Foam (stainless steel shell)	5
Aqueous film forming foam (AFFF)	5
Loaded stream	5
Dry chemical with stainless steel	5
Carbon dioxide	5
Dry chemical, stored pressure, with mild steel, brazed brass, or aluminum shells	12
Dry chemical, cartridge or cylinder operated, with mild steel shells	12
Halon 1211	12
Halon 1301	12
Dry powder, cartridge, or cylinder operated with mild steel shells	12

[a]*Extinguishers having shells constructed of copper or brass joined by soft solder or rivets shall not be hydrostatically tested and shall be removed from services by January 1, 1982.*

Fire Extinguisher Inspections and Service Requirements

An employer is responsible for ensuring that the inspection, maintenance, and testing of all portable fire extinguishers are conducted. Portable fire extinguishers shall be visually inspected monthly. Furthermore, the employer shall ensure that each portable fire extinguisher is serviced annually and tested in accordance with Table 10.2.[2]

Automatic Sprinkler Systems

There are several categories of sprinkler systems that may include dry pipe, wet pipe, deluge, combined dry pipe and pre-action, and sprinklers that are designed for limited water supply systems. A fire sprinkler system consists of a water supply that provides adequate pressure and flow rate to a water distribution piping system, which has sprinkler heads attached. The sprinkler heads are held closed by either a heat-sensitive glass bulb or a two-part metal link held together with fusible alloy. The sprinkler heads have varying degrees of temperature sensitivity and are color coded. These color codes are identified in Table 12.3.

Dry Pipe Systems

Dry pipe systems are normally installed in areas where there is a potential for freezing, which would render the system basically inoperable when needed. For example, dry pipe systems are normally installed in parking garages, unheated buildings, or outside canopies that may be attached to buildings. According to the NFPA, dry pipe systems cannot be installed unless the range of ambient temperatures reaches below 40°F. In this type of

TABLE 12.3

Sprinkler Head Color Codes (Summary of NFPA 13)

Maximum Ceiling Temperature		
°C	°F	Color Code
38	100	Uncolored
66	150	White
107	225	Blue
150	300	Red
190	375	Green
218	425	Orange
246	475	Orange

system, water is not present in the pipe until the system is triggered and the water is released into the distribution system.

Wet Pipe Systems

Wet pipe systems are the most frequently installed systems. In this type of system, water is always present inside the piping distribution system. Once the sprinkler head is opened, the water in the distribution system will flow out of the distribution system.

Deluge Systems

Deluge systems are primarily installed in areas where special hazards exist and the rapid spread of fire is a major concern. In deluge systems, the heat sensors from the sprinkler heads have been intentionally removed. There is no water stored in the distribution system. The water is released into the piping distribution system by the activation of a *deluge valve*, which is triggered by a fire alarm system. Deluge systems must be manually reset by resetting the deluge valve.

Pre-action Systems

Pre-action systems are basically hybrids of wet, dry, and deluge systems. In a pre-action system, a water supply valve is added to a dry pipe system. The valve itself is opened by the activation of a fire detection system, such as a fire alarm or smoke detector. Once activated, the water supply valve will send water to the distribution system. This type of system is normally placed in areas where accidental discharge is undesirable. Typical areas include data centers, museums, and art centers.

Water Spray Systems

Water spray systems operate in the same fashion as deluge systems. However, the piping and discharge nozzle spray patterns are designed to protect a uniquely configured hazard. Such patterns are designed for three-dimensional components or equipment, whereas the deluge systems are designed to cover the floor area of a space.

Foam Water Sprinkler Systems

For special applications, the foam water sprinkler may be used. Foam water sprinkler systems discharge a mixture of water and low-expansion foam concentrate, which results in a foam spray from the sprinkler head. These systems are usually used in areas that have high-challenge fires, such as flammable liquids and airport hangars.

TABLE 12.4

Fire Hydrant Color Code System (Summary from NFPA 291)

Fire Hydrant Top Color	Flow Rate (GPM, gallons per minute)
Red	500
Orange	500–999
Green	1000–1499
Blue	1500 or more

Fire Hydrants

A fire hydrant is an active fire protection measure that provides a source of water from the municipal water system or another source. Buildings located near fire hydrants may qualify for special insurance rate reductions based on their proximity to the hydrant. Fire hydrants are color coded to indicate their specific water flow rate. Table 12.4 illustrates the color codes and flow rates of various fire hydrants.

Fire Detection

There are wide varieties of fire detectors on the market, including heat detectors, rate-compensation detectors, rate-of-rise detectors, pneumatic detectors, smoke detectors, and flame detectors. We will discuss each of these individually in this section.

Heat Detectors

Heat detectors are devices that are installed in fixed locations. These devices respond to changes in the ambient temperature above a predetermined temperature. Once the ambient temperature rises above the predetermined temperature, the alarm is triggered, indicating a potential fire. When selecting a heat detector, it is important to know the maximum normal temperature. For example, installing a 135°F heat detector near a beam of a metal building in hot climates may falsely trigger the alarm.

Rate-of-Rise Heat Detectors

Rate-of-rise heat detectors react to the sudden change or rise in ambient temperature from a normal baseline condition. The sudden temperature increase that matches the predetermined alarm criteria will trigger an alarm.

Rate-Compensation Detectors

While the fixed-temperature heat detector will not initiate an alarm until the air temperature near the ceiling exceeds the design operating point, the rate-of-rise detector will, as the effect of flaming fires is to heat the surrounding air rapidly. Rate-of-rise detectors are designed to compensate for the normal changes in ambient temperature that are expected under non-fire conditions.

Smoke Detectors

Smoke detectors are classified according to their operating principles, which include ionization and photoelectric-type detectors. *Ionization detectors* operate by using a small amount of radioactive material to ionize the air within a sensing chamber inside the detector. The ionization of the air permits the air to conduct electricity between two electrodes within this chamber. As smoke enters the chamber, the smoke particles become ionized and reduce the conductivity of the air between the electrodes. This reduction in conductivity between the electrodes is sensed and will cause the detector to respond.

Photoelectric detectors operate on one of three different principles: light obscuration principle, light scattering principle, or cloud chamber principle. Light obscuration photoelectric detectors operate by projecting a light beam onto a photosensitive device. As smoke particles enter the chamber between the light source and the photosensitive device, the light intensity diminishes and initiates an alarm at a predetermined level. Light scattering detectors operate with a light source and a photosensitive device. In this device, the photosensitive device is not in the light beam path. As smoke particles enter the sensing chamber, light is reflected (scattered) from the smoke particles onto the photosensitive device, causing the detector to alarm. The cloud chamber operating principle draws an air sample from the protected area into a high-humidity chamber within the detector. After the air samples have been raised to high humidity, the pressure is slightly lowered. If smoke particles are in the chamber, a cloud will form. The density of this cloud is measured with a photoelectric device. When the "cloud" reaches a predetermined density, the detector will respond with an alarm.[3]

Fire Hydrants

Fire hydrant caps are color coded to indicate the specific flow rates of the hydrants. Table 10.4 illustrates the fire hydrant color and flow rates.

Flammable and Combustible Liquids

As mentioned earlier in Definitions, a flammable liquid is any liquid having a flash point below 140°F and a vapor pressure not exceeding 40 psia at 100°F.

TABLE 12.5

Characteristics of Flammable Liquids by Class

Classes of Flammable Liquids	
Class	**Characteristics**
IA	**Flash point below 73°F; boiling point below 100°F**
IB	**Flash point below 73°F; boiling point at or above 100°F**
IC	**Flash point at or above 73°F, but below 100°F**

TABLE 12.6

Characteristics of Combustible Liquids by Class

Classes of Combustible Liquids	
Class	**Characteristics**
II	Liquids having flash points at or above 100°F and below 140°F
IIIA	Liquids having flash points at or above 140°F and below 200°F
IIIB	Liquids having flash points at or above 200°F

A combustible liquid is any liquid having a flash point at or above 140°F and below 200°F. The NFPA has classified flammable liquids into three classes according to their boiling points. These classes are identified in Table 10.5.

When taking the ASP or CSP examination, it is highly recommended that you commit to memory Tables 12.5 and 12.6. Table 12.5

The NFPA has also classified combustible liquids into three classes according to their flash points. These classifications are illustrated in Table 12.6.

To further understand flammable and combustible liquids, it is necessary to understand some of the individual properties associated with them. Each of the properties listed below will be referenced on safety data sheets (SDSs), along with their assigned values for the substances listed on the SDS. The following are key properties that will be discussed in more detail.

Flash Point

We have already defined the flash point as the minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid. The flash point is normally an indication of susceptibility to ignition.

Vapor Pressure

The *vapor pressure* of a liquid is defined as the pressure exerted by the molecules that escape from the liquid to form a separate vapor phase above the liquid surface. The pressure exerted by the vapor phase is called the vapor or saturation pressure. Vapor or saturation pressure depends on

temperature. As the temperature of a liquid or solid increases, its vapor pressure also increases. Conversely, vapor pressure decreases as the temperature decreases.

If fluids consist of more than one component, then components with high vapor pressures are called light components and those with lower vapor pressures are called heavy components.

Fire Point

Fire point is closely related to the flash point. However, the fire point is defined as the temperature at which a substance will give off a vapor that will burn continuously after ignition. Usually, the fire point is higher than the flash point.

Flammable and Explosive Limit Ranges

Flammability limits, or *explosive limits*, give the proportion of combustible gases in a mixture. Concentrations between the lower and upper limits of the mixture are flammable or explosive. The lower flammable limit (LFL) or the lower explosive limit (LEL) is the leanest mixture that is still flammable or explosive. Conversely, the upper flammable limit (UFL) or upper explosive limit (UEL) is the richest mixture that is still flammable or explosive. These concentrations are given in percentage of air.

Table 10.7 lists some of the more commonly used gases that are used as fuel or in combustion processes along with their LFL and UFL.

Autoignition Temperature

The autoignition temperature, also referred to as the kindling point, is the lowest temperature at which a substance will ignite in a normal atmosphere without an external source of ignition from a spark or flame. The temperature at which a chemical will ignite decreases as the pressure increases or oxygen concentration increases.

Specific Gravity

The specific gravity describes the density of a liquid compared to the density of water. Liquids with a specific gravity of one or less (≤ 1) are lighter than water, and those with specific gravities greater than or equal to one (≥ 1) are heavier than water. Specific gravity is particularly important when addressing chemical spills.

TABLE 12.7

Lower and Upper Flammability/Explosive Limits for Common Chemicals

Chemical	LFL/LEL	UFL/UEL
Acetaldehyde	4	60
Acetone	2.6	12.8
Acetylene	2.5	81
Ammonia	15	28
Arsine	5.1	78
Benzene	1.35	6.65
n-Butane	1.86	8.41
iso-Butane	1.80	8.44
iso-Butene	1.8	9.0
Butylene	1.98	9.65
Carbon disulfide	1.3	50
Carbon monoxide	12	75
Cyclohexane	1.3	8
Cyclopropane	2.4	10.4
Diethyl ether	1.9	36
Ethane	3	12.4
Ethylene	2.75	28.6
Ethyl alcohol	3.3	19
Ethyl chloride	3.8	15.4
Fuel oil no. 1	0.7	5
Hydrogen	4	75
Isobutane	1.8	9.6
Isopropyl alcohol	2	12
Gasoline	1.4	7.6
Kerosene	0.7	5
Methane	5	15
Methyl alcohol	6.7	36
Methyl chloride	10.7	17.4
Methyl ethyl ketone	1.8	10
Naphthalene	0.9	5.9
n-Heptane	1.0	6.0
n-Hexane	1.25	7.0
n-Pentane	1.65	7.7
Neohexane	1.19	7.58
Neopentane	1.38	7.22
n-Octane	0.95	3.20
iso-Octane	0.79	5.94
n-Pentane	1.4	7.8
iso-Pentane	1.32	9.16
Propane	2.1	10.1
Propylene	2.0	11.1
Silane	1.5	98
Styrene	1.1	6.1
Toluene	1.27	6.75
Triptane	1.08	0.69
p-Xylene	1.0	6.0

Note: Limits are for gas and air at 20°C and atmospheric pressure.

Vapor Density

Like specific gravity, vapor density is a measure of the density of a substance compared to air. Gases and vapors with densities greater than or equal to one (≥1) are heavier than air and will tend to sink to lower levels. Those gases and vapors with densities less than or equal to one (≤1) are lighter than air and will tend to float upward. Knowing the vapor density of a substance is useful in determining the location of the ventilation system. For example, substances with vapor densities greater than one will sink. Therefore, the ventilation should be located near the floor or the lower level of the area.

Evaporation Rate

The evaporation rate is the rate at which a liquid is converted to vapor at a given temperature and pressure. Butyl acetate, which has an evaporation rate of 1, is the standard by which most substances are compared. Therefore, if a substance has an evaporation rate of less than one, it will evaporate more slowly than butyl acetate.

Water Solubility

Water solubility, which is also known as aqueous solubility, is the maximum amount of a substance that can dissolve in water at equilibrium at a given temperature and pressure. Water solubility (S_w) values are usually expressed as moles of solute per liter. The term *water solubility* is primarily used in many environmental studies to help determine the fate of chemicals in the environment (http://toxics.usgs.gov/definitions/water_solubility.html).

Boiling Point

The boiling point of a substance is the temperature at which the vapor pressure of the liquid is equal to the environmental pressure surrounding the liquid. It is the temperature at which the liquid is converted into vapor.

Storage Requirements for Flammable and Combustible Liquids

Tables 12.8[4] and 12.9 show the maximum allowable size of containers for flammable and combustible liquids, respectively.,

Inside Storage Rooms for Flammable or Combustible Liquids

When flammable or combustible liquids are stored in inside rooms, the storage room shall be equipped with either a gravity or a mechanical exhaust

TABLE 12.8

Maximum Allowable Size of Containers for Flammable Liquids (OSHA)

	Flammable Liquids		
Container Type	**Class IA**	**Class IB**	**Class IC**
Glass or approved plastic	1 pt	1 qt	1 gal
Metal (other than DOT drums)	1 gal	5 gal	5 gal
Safety cans	2 gal	5 gal	5 gal
Metal drums (DOT specifications)	60 gal	60 gal	60 gal
Approved portable tanks	660 gal	660 gal	660 gal

TABLE 12.9

Maximum Allowable Size of Containers for Combustible Liquids (OSHA)

	Combustible Liquids	
Container Type	**Class II**	**Class III**
Glass or approved plastic	1 gal	1 gal
Metal (other than DOT drums)	5 gal	5 gal
Safety cans	5 gal	5 gal
Metal drums (DOT specifications)	60 gal	60 gal
Approved portable tanks	660 gal	660 gal

TABLE 12.10

Inside Storage Room Maximum Quantities per Square Foot (OSHA)

Fire Protection Provided[a]	**Fire Resistance (h)**	**Maximum Size (ft^2)**	**Total Allowable Quantities (gal/ft^2)**
Yes	2	500	10
No	2	500	5
Yes	1	150	4
No	1	150	2

ventilation system. This system shall be designed to provide a complete change of air within the room at least six times per hour. In addition, in each inside storage room, there shall be maintained one clear aisle at least 3 ft wide. Containers over 30-gal capacity will not be stacked one upon the other. Table 12.10 illustrates the maximum storage capacity for any inside storage room.

Key Information to Remember on Fire Prevention and Protection

1. Radiation heat is the amount of thermal radiation between two or more objects (bodies).
2. Convection can be defined as the process whereby thermal energy is transferred by the movement of a heated fluid such as liquid or air.
3. Conduction is the transfer of thermal energy between two objects in contact with each other.
4. According to the NFPA, fires can be classified as A, B, C, D, or K.
5. Portable fire extinguishers shall be visually inspected monthly.
6. Portable fire extinguishers shall be serviced annually and hydrostatically tested at 5 or 12 years, depending on their shell.
7. The lower flammability limit or lower explosive limit is the leanest mixture that is still flammable or explosive.
8. The upper flammability limit, or upper explosive limit, is the richest mixture that is still flammable or combustible.

References

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13

Thermal Stressors

In today's work environments, there are a wide variety of temperatures, not only outdoor temperatures, but indoors, as well. Thermal stress can be a problem in indoor operations, such as boiler maintenance after a "shutdown," smelting operations, laundries and kitchens, foundries, brick firing and ceramic operations, and work in refrigerated rooms or freezers. Oftentimes, the personal protective equipment used to protect employees from one type of injury can create additional hazards from thermal stress. Thermal stress should be considered when selecting the appropriate personal protective equipment and to determine work/rest cycles.

Thermal stress, whether heat or cold, can increase the risk of accidents in the workplace by causing fatigue. Employees exposed to extreme hot or cold temperatures may have a hard time concentrating on work and ignore safety. The Occupational Safety and Health Administration (OSHA) does not have a special standard for thermal stress. However, since thermal stress is considered a hazard, the employee is protected under OSHA's General Duty Clause, which states that "employers shall provide a workplace free of recognized hazards...."[1]

Heat Stress

Heat stress is of great concern in the workplace, as well as during recreational activities. It is caused by a combination of factors and tends to increase body temperature, heart rate, and sweating.

Sources of Heat Stress

There are four basic sources of heat to the body, which include (1) radiation, (2) convection, (3) conduction, and (4) metabolic. It is important to understand the process of heat transfer. Heat always moves from a warmer place to a cooler place. Hot objects in a cooler room will eventually cool to room temperature. Cold objects in a warmer room will heat up to room temperature. *Radiation* heat is the amount of thermal radiation between two or more objects (bodies). Radiation travels in wavelengths and does not require that the two objects be in contact, as radiation can travel through a vacuum or

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space. *Convection* can be defined as the process whereby thermal energy is transferred by the movement of a heated fluid such as liquid or air. *Conduction* is the transfer of thermal energy between two objects in contact with each other. *Metabolic* heat is generated from within the body through work. Metabolic heat is the source of greatest concern since it has the potential to overheat the body.

Human Body Reaction to Heat

What happens to the human body when exposed to heat? The human body, as with all other organisms, has a system of thermoregulation, which helps maintain body temperature within a certain range. The survival range for the human body is between 97°F and 100°F, with a normal temperature of approximately 98.6°F. When exposed to heat extremes, the body must regulate itself to stay within this temperature range. To do so, the body must get rid of the excess heat by varying the rate and amount of blood circulation through the skin and releasing sweat from the glands. This is accomplished when the heart begins to pump more blood, the blood vessels expand to accommodate the increased flow, and the capillaries that are located along the upper layer of the skin begin to fill with blood. The blood then circulates closer to the surface of the skin, and excess heat is lost to the cooler environment. The cooled blood returns to the core of the body, picks up more heat, and carries it to the surface. This process is repeated until the core temperature reaches a state of homeostasis.

The sweat that appears on the surface of the skin is evaporated by the cooler temperatures outside the body. The evaporation of sweat cools the skin, thereby eliminating heat from the body. The problem that is encountered in this process is that when environmental temperatures outside the body approach normal skin temperature, the cooling process becomes more difficult. However, the heart continues to pump blood to the surface, the sweat glands pour liquids containing electrolytes onto the surface of the skin, and the evaporation of the sweat becomes the principal effective means of cooling.

If the sweat is not removed from the skin by evaporation, it will not cool the body. Under conditions of high humidity, the evaporation of sweat from the skin is decreased, and the body's efforts to maintain an acceptable body temperature may be significantly impaired. With so much blood going to the external surface of the body, less is going to the active muscles, the brain, and other organs; strength declines; and fatigue occurs sooner than normal. Alertness and mental capacity also may be affected. Workers who must perform delicate or detailed work may find their accuracy decreases, and others may find their comprehension and retention of information lowered.[1]

Safety-Related Issues of Heat

In addition to the health-related issues, there are a wide variety of safety issues related to heat and heat stress. Heat in the workplace tends to promote

accidents by means of sweaty and slippery palms, dizziness, fatigue, decreased alertness, and possibly the fogging of safety glasses or goggles. Physical discomfort increases irritability, anger, and other emotional states that sometimes cause workers to overlook safety procedures or divert attention from hazardous tasks. Combined with longer shifts, there is a greater risk of accidents and health problems.

Health-Related Issues of Heat

Extended exposure to heat extremes brings about a wide variety of heat-induced disorders. Managers and supervisors should ensure that all workers exposed to potential heat are trained in the signs and symptoms of these disorders and how to prevent them. The disorders that will be discussed include heat rash, heat cramps, heat syncope, dehydration, heat exhaustion, and heat stroke.

Heat Rash

Heat rash is most likely to occur in hot, humid environments where sweat is not easily removed from the surface of the skin through evaporation and the skin remains wet most of the time. For example, sweat remains trapped in the clothing of an employee and can possibly cause a rash related to heat. The causes of heat rash are prolonged, uninterrupted sweating and poor hygiene. The signs and symptoms of heat rash include skin eruptions, itchy red skin, and reduced sweating. The prevention of heat rash includes keeping the skin clean and periodically allowing the skin to dry. If heat rash occurs, clean and dry the skin, change into dry clothing, and reduce heat exposure. Medical attention may include topical ointments to prevent any bacteriological infection.

Heat Cramps

Heat cramps result in individuals who sweat profusely in heat, drink large quantities of water, and do not adequately replace the body salts that are lost through sweating. Heat cramps are painful spasms of the muscles caused by the loss of electrolytes. The signs and symptoms of heat cramps include painful muscle cramps and incapacitating pain in the muscles. To prevent heat cramps, workers should drink plenty of fluids and add salt to their diets. Normal salting of food is considered adequate to reduce the possibility of heat cramps. In extremely hot environments, drinking water is encouraged. However, about every third time a person drinks, it is recommended that they drink some type of sports drink to help replace the lost electrolytes.

Heat Syncope

Heat syncope is fainting as a result of exposure to heat. It is caused by mild overheating with inadequate water or salt. The signs and symptoms of heat

syncope include blurred vision, fainting, and normal body temperature. The main cause of heat syncope is pooling of blood in the legs and skin from prolonged static posture and heat exposure. To prevent heat syncope, it is important to flex the leg muscles several times before moving and to stand or sit up slowly. Should heat syncope occur, have the affected employee lie on their back in a cool environment and drink water.

Dehydration

Dehydration occurs when the amount of water leaving the body is greater than the amount being taken in. There are no early symptoms of dehydration. However, signs and symptoms in later stages include fatigue, weakness, dry mouth, the loss of work capacity, and increased response time. A rule of thumb when referring to dehydration is that if you are thirsty, then dehydration has already occurred. Major contributing factors to dehydration include excess fluid loss (through sweating or other means), alcohol consumption, and some medications. In order to prevent dehydration, employees are encouraged to drink water frequently and to use normal salt in their diets. Once dehydration has occurred, fluid and salt replacement are required.

Heat Exhaustion

Heat exhaustion is caused by the loss of large amounts of fluid and salts through excessive sweating. Workers suffering from heat exhaustion still sweat but experience extreme fatigue or loss of consciousness. If heat exhaustion is not treated, the illness may advance to heat stroke. The signs and symptoms of heat exhaustion include fatigue, weakness, blurred vision, dizziness, high pulse rate, profuse sweating, low blood pressure, pale face, clammy skin, collapse, nausea and vomiting, headaches, and slightly increased body temperature. The major causes of heat exhaustion are dehydration, low level of acclimation, and low level of physical fitness. To prevent heat exhaustion, an employee should drink water or other fluids (sports drinks) frequently, take normal salt in their diets, take rest breaks in a cool area, and acclimate themselves to the environment. The treatment for heat exhaustion is to have the affected person lie down flat on their back in a cool environment, drink water, cool their skin with a cool mist or wet cloth, and loosen their clothing (especially at the neck, waist, and feet or ankles). Many medical experts conclude that once a person has experienced heat exhaustion, they are more susceptible to a second experience with heat exhaustion. Therefore, it would be helpful to know which persons are more susceptible before beginning a project in a hot environment.

Heat Stroke

Heat stroke is considered a **MEDICAL EMERGENCY**! It occurs when the body's temperature regulation system fails, and sweating becomes inadequate or stops entirely. Without treatment, death or brain damage is almost

certain. The signs and symptoms of heat stroke include chills, restlessness, irritability, mental confusion; euphoria; red face; disorientation; hot, dry skin; cessation of sweating, erratic behavior; collapse; shivering; unconsciousness; convulsions; and a core body temperature greater than 104°F. The major cause of heat stroke is excessive workloads in hot environments. To prevent heat stroke, individuals should acclimate themselves to the environment, lead a healthy lifestyle, adhere to an appropriate work/rest cycle, drink plenty of fluids, maintain a proper diet, and self-determine the amount and length of heat stress exposure they can tolerate.

Control Methods

As with any hazard associated with the workplace, OSHA requires that engineering controls, administrative controls, and personal protective equipment be used in that order to prevent work-related injuries.

Engineering Controls

To control heat in the work environments, a wide variety of techniques can be utilized. *General ventilation* is used to dilute hot air with cooler air. General ventilation works better in cooler climates than in hot ones. It is usually permanently installed to handle larger areas or entire buildings. When dealing with smaller areas, portable or local exhaust systems may be more effective or practical. *Air treatment or air cooling* differs from ventilation because it reduces the temperature of the air by removing the heat and sometimes the humidity from the air. *Air conditioning* is an effective method for cooling, but it is expensive to install and operate. An alternative to air conditioning is the use of chillers to circulate cool water through heat exchangers over which air from the ventilation system is then passed. *Convection fans* can be set up in hot areas and can increase heat exchange and the rate of evaporation, provided that the air temperature is less than body temperature. *Insulating* hot surfaces or tools that generate or conduct heat can also reduce heat conduction to workers. *Heat shields* can be used to reduce radiant heat when placed between a heat source and workers. Polished surfaces make the best barriers, although special glass or metal mesh surfaces can be used if visibility is a concern. Shields should be located so that they do not interfere with airflow unless they are being used to reduce convective heating. Mechanization of work procedures can often make it possible to isolate workers from the heat source (air-conditioned booth) and increase productivity by decreasing the rest time needed and metabolic heat produced. *Reduction in air humidity* can be accomplished by removing the water from the air with chillers or mechanical refrigeration. By lowering the humidity in the air, the rate of evaporation of sweat increases.[1]

Administrative and Work Practice Controls

Acclimation or Acclimatization

Acclimation or acclimatization is the process of the body adapting to a change in temperature. For humans, the process of acclimatization can take up to 2 weeks. After acclimation occurs, the body can perform normal activities in the new environment with fewer cardiovascular demands. Since the process of acclimation is gradual, the work demands on a worker should also be gradual. A good rule of thumb for workers exposed to extreme temperatures is to expose them to approximately 20% more each day for 5 days. Good physical conditioning also reduces the cardiovascular demands on people. New employees should be closely monitored for signs and symptoms of heat-related injuries.

Fluid Replacement

While working in hot environments, workers can produce as much as 2–3 gal of sweat. Therefore, the replacement of these fluids should be about equal to the amount of sweat produced. In addition to fluid replacement, workers should also continue to eat normal or near-normal meals, which is often difficult since the appetite in hot environments is greatly decreased. Fluids high in caffeine are not recommended. Extremely cold fluids should also be avoided in hot environments. The amount of fluids to be replaced at various temperatures will be discussed later.

Work/Rest Cycles

Depending on the amount of work being performed and the environmental temperatures, workers in hot environments need more break periods than unexposed workers do. Rest breaks are used to reduce the metabolic heat produced by the body during work and to aid in cooling. When determining work/rest cycles, the Wet Bulb Globe Temperature (WBGT) Index and the workload must be evaluated. To determine the metabolic rate (time-weighted average), we can use the following equation:

$$\text{Average}_{\text{Metabolic}} = \frac{(M_1)(T_1)+(M_2)(T_2)+\cdots(M_n)(T_n)}{(T_1)+(T_2)+\cdots(T_n)},$$

where

M = metabolic rate (kcal/min)
T = time (min)

Table 13.1 illustrates an assessment of work in relation to body position and movement.

TABLE 13.1

Assessment of Work by Body Position and Movement

Body Position and Movement	kcal/min[a]
Sitting	0.3
Standing	0.6
Walking	2.0–3.0
Walking uphill	Add 0.8 for every meter or yard rise

Source: U.S. Department of Labor, Occupational Safety and Health Administration, *Technical Manual (TED 01-00-015),* http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html.

[a] *For a "standard" worker of 70 kg (154 lb) body weight and 1.8 m^2 (19.4 ft^2) body surface.*

TABLE 13.2

Assessment of Work by Type of Work Being Performed

Type of Work	kcal/min	Range (kcal/min)
Hand Work		
Light	0.4	0.2–1.2
Heavy	0.9	
Work: One Arm		
Light	1.0	0.7–2.5
Heavy	1.7	
Work: Both Arms		
Light	1.5	1.0–3.5
Heavy	2.5	
Work: Whole Body		
Light	3.5	2.5–15.0
Moderate	5.0	
Heavy	7.0	
Very heavy	9.0	

Source: U.S. Department of Labor, Occupational Safety and Health Administration, *Technical Manual (TED 01-00-015)*, http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html.

Table 13.2 illustrates an assessment of work in relation to the type of work being performed.

Using the equation above, determine the average metabolic rate for an employee who shovels gravel for 1.5 h at a metabolic rate of 7.0 kcal/min, takes a break for 30 min in a sitting position (metabolic rate = 0.3 kcal/min), resumes working on constructing a concrete form for 4 h (metabolic rate = 3.5 kcal/min), and finally pours and finishes the concrete (metabolic rate = 5.0 kcal/min) for 2 h. What is the average metabolic rate?

$$\text{Average}_{\text{M}}$$

$$= \frac{(7.0\text{ kcal})(90\text{ min}) + (0.3\text{ kcal})(30\text{ min}) + (3.5\text{ kcal})(240\text{ min}) + (5.0\text{ kcal})(120\text{ min})}{480\text{ min}}$$

$$= \frac{630\text{ kcal} + 9\text{ kcal} + 840\text{ kcal} + 600\text{ kcal}}{480}$$

$$= \frac{2079}{480}$$

$$= 4.33\text{ kcal / min.}$$

The average metabolic rate for this work is 4.33 kcal/min. Multiplied by 60 min, the metabolic rate would be 259.8 kcal/h. Workload categories are determined by averaging metabolic rates for the tasks and then ranking them as follows:

- Light work: up to 200 kcal/h
- Medium work: 200–350 kcal/h
- Heavy work: 350–500 kcal/h

Therefore, the total work described in the example would be categorized as moderate work. Determining the average metabolic rate is only part of the equation in setting work rest schedules, we must now calculate the WBGT Index using the appropriate calculation. The average WBGT is calculated as follows:

$$\text{Average}_{\text{WBGT}} = \frac{(\text{WBGT}_1)(t_1) \pm (\text{WBGT}_2)(t_2) + \cdots + (\text{WBGT}_n)(t_n)}{(t_1) + (t_2) + \cdots (t_n)}.$$

For indoor and outdoor conditions with no solar load, WBGT is calculated as

$$\text{WBGT} = 0.7\text{ WB} + 0.3\text{ GT.}$$

For outdoors with a solar load, WBGT is calculated as

$$\text{WBGT} = 0.7\text{ WB} + 0.2\text{ GT} + 0.1\text{ DB,}$$

where
WBGT = Wet Bulb Globe Temperature Index
WB = wet-bulb temperature
DB = dry-bulb temperature
GT = globe temperature

TABLE 13.3

Permissible Heat Exposure Threshold Limit Value

	Workload		
Work/Rest Cycle	**Light**	**Moderate**	**Heavy**
Continuous	30.0°C (86°F)	26.7°C (80°F)	25.0°C (77°F)
75% Work, 25% rest, each hour	30.6°C (87°F)	28.0°C (82°F)	25.9°C (78°F)
50% Work, 50% rest, each hour	31.4°C (89°F)	29.4°C (85°F)	27.9°C (82°F)
25% Work, 75% rest, each hour	32.2°C (90°F)	31.1°C (88°F)	30.0°C (86°F)

Source: U.S. Department of Labor, Occupational Safety and Health Administration, *Technical Manual (TED 01-00-015),* http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html.

Note: These TLVs are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C (100.4°F). They are also based on the assumption that the WBGT of the resting place is the same or very close to that of the workplace. Where the WBGT of the work area is different from that of the rest area, a time-weighted average should be used (consult the ACGIH *1992–1993 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices).*

TABLE 13.4

WBGT Correction Factors for Clothing

Clothing Type	**Clo[a] Value**	**WBGT Correction (°C)**	**WBGT Correction (°F)**
Summer, lightweight working clothing	0.6	0	32
Cotton overalls	1.0	−2	28
Winter work clothing	1.4	−4	25
Water barrier, permeable	1.2	−6	21

Source: U.S. Department of Labor, Occupational Safety and Health Administration, *Technical Manual (TED 01-00-015),* http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html.

[a] Clothes: Insulation value of clothing. One clo = 5.55 kcal/m^2/h of heat exchange by radiation and convection for each degree Celsius difference in temperature between the skin and the adjusted dry-bulb temperature.

By calculating both the WBGT Index and the average metabolic rate of the employees, we can now establish the work/rest cycle for each group of employees. The work/rest cycle can be determined by using Table 11.3 provided by the ACGIH Threshold Limit Values for Chemical Substances and Physical Agents and Biological Indices.

By way of example, the work scenario described previously was performed outdoors as follows:

WBGT of 79° for 90 min, WBGT of 74° for 30 min, WBGT of 86° for 240 min, and 88° for 120 min. What is the average WBGT Index?

These TLVs apply to physically fit and acclimatized individuals wearing light summer clothing. If heavier clothing that impedes sweat or has a higher insulation value is required, the permissible heat exposure TLVs in Table 13.3 must be reduced by the corrections shown in Table 13.4.

$$\text{Average}_{\text{WBGT}} = \frac{(79°)(90\,\text{min}) + (74°)(30\,\text{min}) + (86°)(240\,\text{min}) + (88°)(120\,\text{min})}{480\,\text{min}}$$

$$= \frac{(7110) + (2220) + (20,640) + (10,560)}{480}$$

$$= \frac{40,530}{480}$$

$$= 84.44°\text{F}.$$

Using Table 13.3, the appropriate work/rest cycle for moderate work would be to work for 30 min and rest for 30 min each hour.

Personal Protective Equipment

Reflective clothing, which can vary from aprons and jackets to suits that completely enclose the worker from neck to feet, can stop the skin from absorbing radiant heat. However, since most reflective clothing does not allow air exchange through the garment, the reduction of radiant heat must more than offset the corresponding loss in evaporative cooling. Reflective clothing should be worn as loosely as possible. In situations where radiant heat is high, auxiliary cooling systems can be used under the reflective clothing. Auxiliary body cooling can also be used to reduce some of the heat stress. Auxiliary cooling options include ice vests, water-cooled garments, circulating air, and wetted terry-cloth coveralls or cotton suits (effective under low humidity). Respirators and other personal protective equipment increase the stress on a worker, and this stress contributes to overall heat stress. Chemical protection suits will also add to the heat stress problem, as well as protective vests worn by military and police officers. The effects of this protective equipment must be considered when determining workloads and work/rest cycles.[1]

In addition, employees exposed to direct sunlight should protect their exposed skin (neck, face, hands, and arms) using a sunblock/cream of at least 15 SPF. A wetted scarf can also be worn around the neck to aid in cooling.[2]

Training

Training is the key to good work practices. An effective heat stress training program should include at least the following elements:

- Knowledge of the hazards of heat stress
- Recognition of predisposing factors, danger signs, and symptoms
- Awareness of first-aid procedures for, and the potential effects of, heat-related disorders
- Employee responsibilities in avoiding heat stress
- Use of personal protective clothing and equipment
- Physical fitness to prevent heat-related disorders
- Fluid replacement
- Dangers of drugs and alcohol in hot work environments
- Purpose and coverage of environmental and medical surveillance programs

Prevention of Heat Stress Injuries

Heat-related disorders can be prevented through various means. As you have seen in this chapter, predisposing factors to heat-related disorders may include age, fairness of skin, health, medication, caffeine and alcohol consumption, and general physical conditioning. Therefore, the prevention of heat-related injuries begins with knowing these factors. Additional measures of prevention include the following:

- Learning the signs and symptoms of heat-related disorders
- Training workers about heat-related illnesses
- Performing the heaviest work in the coolest part of the day
- Acclimation of employees
- Using the buddy system (working in pairs)
- Adequate fluid replacement (one cup of water every 15–20 min)
- Wear light, loose-fitting, breathable clothing
- Adhere to the work/rest cycle
- Avoid caffeine and alcoholic beverages
- Wear appropriate personal protective equipment

Cold Stress

As we discussed in the Heat Stress section of this chapter, heat (and particularly body heat) can be lost through four different means: (a) radiation, (b) conduction, (c) convection, and (d) evaporation. Through radiation, body heat is lost to the colder environment since heat will always travel to the

cooler area. Body heat may be lost through direct contact with another cooler object. Through convection, molecules against the surface of a warm body are moved away and replaced by cold ones. For example, wind chill may play an important factor in body heat by removing heat and replacing it with cold against the skin. In evaporation, heat and fluid are lost to the environment from sweating and respiration. A decreased fluid level makes the body more susceptible to hypothermia and other cold injuries.

In the Heat Stress section of this chapter, we also discussed how heat is gained through the normal functioning of the body to regulate its internal temperature. When exposed to cold extremes, the body's first reaction is to conserve body heat by reducing blood circulation through the skin, which makes the skin an insulating layer. The next reaction when confronted with cold extremes is that the body begins to shiver in order to increase the rate of metabolism. Shivering is actually a good sign that cold stress is significant, and hypothermia may be present. Behavioral responses to cold include increasing clothing insulation, increasing activity, and seeking warmth.

Safety Problems Related to Cold

Just as in heat stress, when employees are uncomfortable (stress), they do not pay as much attention to their jobs or tasks at hand. Therefore, accidents are more likely to occur from inattention. Cold stress will also cause employees to become more rapidly fatigued.

Cold-Related Injuries and Illnesses

Cold-related injuries can be divided into two types: nonfreezing and freezing injuries. Nonfreezing injuries can include chilblains, immersion injuries, and mild, moderate, and severe hypothermia. A freezing injury includes frostbite of varying degrees. Obviously, nonfreezing injuries occur when environmental temperatures are above 32°F, while freezing injuries occur when temperatures fall below freezing. Each of these injuries will be discussed individually.

Chilblains

Chilblains, also known as *pernio* or *perniosis*, are itchy and tender red or purple bumps that occur as a reaction to cold temperatures. Chilblains result from the shutting down of the blood vessels in cold conditions. They occur several hours after exposure to the cold in temperate, humid climates and

are sometimes aggravated by exposure to the sun. The small arteries and veins in the skin constrict from the cold, and rewarming results in leakage of blood into the tissues and swelling of the skin. Contributing factors to chilblains include the following:

- Familial tendency
- Peripheral vascular disease owing to diabetes, smoking, or hyperlipidemia
- Low body weight or poor nutrition
- Hormonal changes (chilblains actually improve during pregnancy)
- Connective tissue disease
- Bone marrow disorders

There is very little treatment for chilblains. Topical steroid creams applied to the skin may relieve the itching. Antibiotic ointments or oral antibiotics may help prevent secondary infections as a result of scratching. Chilblain preventive measures may include the following:

- Insulated and heated homes and workplaces
- Warm clothing, especially gloves, thick woolen socks, and comfortable protective footwear
- Avoid medicines that might constrict blood vessels, including caffeine, decongestants, and diet aids
- Exercise vigorously before going outside
- Wear cotton-lined waterproof gloves for wet work
- Apply sunscreen to exposed skin even on dull days
- Refrain from smoking
- Maintain physical conditioning

Immersion Injuries (Trench Foot)

Immersion injuries result from prolonged exposure to cold weather, usually 12 h or longer at temperatures of 50°F–70°F (10°C–21°C), or for shorter periods at or near 32°F (0°C). Trench foot is an immersion injury seen in trench warfare or other environments where mobility is limited, and dry boots and socks are unobtainable. The injured part is cold, swollen, waxy-white, with cyanotic burgundy-to-blue splotches, and the skin is anesthetic and deep musculoskeletal sensation is lost.

The prevention and treatment of trench foot are similar to the treatment and prevention of frostbite. When possible, air-dry and elevate the feet, and exchange wet shoes and socks for dry ones to help prevent the development of trench foot.

Take the following steps:

- Thoroughly clean and dry your feet.
- Put on clean, dry socks daily.
- Treat the affected part by applying warm packs or soaking it in warm water (102°F–110°F) for approximately 5 min.
- When sleeping or resting, do not wear socks.
- Obtain medical assistance as soon as possible.

If you have a foot wound, your foot may be more prone to infection. Check your feet at least once a day for infections or worsening symptoms.

Hypothermia

Hypothermia is a reduction of the body's core temperature below its normal (98°F), which results in a progressive deterioration in cerebral, musculoskeletal, and cardiac functions. There are three degrees of hypothermia, which are classified by their degree of severity. The three degrees of severity of hypothermia include mild, moderate, and severe hypothermia. Mild hypothermia ranges when the body temperature is 89.6°F–95°F and is initially characterized by violent shivering followed by a virtual cessation of effective muscular activity, disorientation, and disinterest in surroundings. Moderate hypothermia results when the body temperature ranges from 78.8°F to 89.59°F, with cardiac irregularities occurring at approximately 86°F and corneal reflexes absent below 82.4°F. Severe hypothermia occurs at core temperatures of 78.79°F and lower, and with ventricular fibrillation a paramount risk below 80.6°F. At this temperature, the affected person may appear clinically dead. However, cold injury victims have been successfully resuscitated at core temperatures of 64°F, which created the medical saying, "No one is dead until he/she is warm and dead."[3]

Frostbite

Frostbite results from exposure to environmental temperatures below freezing. The speed of onset, depth, and severity of injury depend on temperature, wind chill, and the duration of exposure. Cellular injury and death occur from cellular trauma caused by the formation of ice crystals and from complex vascular reactions occurring in cold exposure. Superficial frostbite involves only the skin or the tissue immediately beneath it, while deep frostbite also affects the deep tissue beneath (including the bone). If the tissue has frozen, it appears "dead white" and is hard or even brittle. Differentiation of the types and severity of injury may be difficult.

First-degree frostbite is similar to mild chilblain with hyperemia (an increase in blood flow to a tissue owing to the presence of metabolites and a change in

general conditions), mild itching, and edema (swelling). There is no blistering or peeling of the skin.

Second-degree frostbite is characterized by blistering and desquamation (shedding of the outer layer of the skin).

Third-degree frostbite is associated with necrosis of skin and subcutaneous tissue with ulceration.

Fourth-degree frostbite includes the destruction of connective tissues and bones, accompanied by gangrene. Secondary infections and the sequelae (pathological conditions resulting from disease, injury, or trauma) noted for nonfreezing injuries are not infrequent, particularly if there is a history of freeze–thaw–refreeze.[3]

The susceptibility of persons to cold injuries includes not being acclimatized, age, previous history of cold injuries, physical fitness, race or origin, nutrition, and use of medicine or alcohol. Full acclimation to cold climates occurs only after approximately 4 weeks.

Frostbite preventive measures include the following:

- Observance and adherence to the wind chill factor
- Proper protective clothing
- Proper nutrition and activity
- Fluid replacement or intake
- Training and discipline

Wind Chill Factor

Wind chill is defined as the number of calories lost during 1 h from a square meter of a surface kept at 91.4°F. The information provided in Table 13.5 shows the wind chill factor at various wind speeds and temperatures.

To calculate the wind chill, the following equation can be used:

$$\text{Wind chill}(^\circ\text{F}) = 35.74 + 0.6215T - 35.75\left(V^{0.16}\right) + 0.4275T\left(V^{0.16}\right),$$

where

T = air temperature (°F)

V = wind speed (mph)

For example, calculate the wind chill for the following: wind speed = 20 mph and a temperature of 10°F.

$$\text{Wind chill}(^\circ\text{F}) = 35.74 + 0.6215(10) - 35.75\left(20^{0.16}\right) + 0.4275(10)\left(20^{0.16}\right)$$

TABLE 13.5

Wind Chill Chart (National Weather Service)

Temp (°F)	Wind Speed (mph)											
Calm	5	10	15	20	25	30	35	40	45	50	55	60
40	36	34	32	30	29	28	28	27	26	26	25	25
35	31	27	25	24	23	22	21	20	19	19	18	17
30	25	21	19	17	16	15	14	13	12	12	11	10
25	19	15	13	11	9	8	7	6	5	4	4	3
20	13	9	6	4	3	1	0	−1	−2	−3	−3	−4
15	7	3	0	−2	−4	−5	−7	−8	−9	−10	−11	−11
10	1	−4	−7	−9	−11	−12	−14	−15	−16	−17	−18	−19
5	−5	−10	−13	−15	−17	−19	−21	−22	−23	−24	−25	−26
0	−11	−16	−19	−22	−24	−26	−27	−29	−30	−31	−32	−33
−5	−16	−22	−26	−29	−31	−33	−34	−36	−37	−38	−39	−40
−10	−22	−28	−32	−35	−37	−39	−41	−43	−44	−45	−46	−48
−15	−28	−35	−39	−42	−44	−46	−48	−50	−51	−52	−54	−55
−20	−34	−41	−45	−48	−51	−53	−55	−57	−58	−60	−61	−62
−25	−40	−47	−51	−55	−58	−60	−62	−64	−65	−67	−68	−69
−30	−46	−53	−58	−61	−64	−67	−69	−71	−72	−74	−75	−76
−35	−52	−59	−64	−68	−71	−73	−76	−78	−79	−81	−82	−84
−40	−57	−66	−71	−74	−78	−80	−82	−84	−86	−88	−89	−91
−45	−63	−72	−77	−81	−84	−87	−89	−91	−93	−95	−97	−98

$$= 35.74 + 6.215 - 35.75(1.62) + 4.275(1.62)$$
$$= 35.74 + 6.215 - 57.92 + 6.93$$
$$= -9.$$

Personal Protective Clothing

The appropriate amount and type of clothing are required to insulate the body from extreme temperatures and to prevent or slow down heat loss to the environment. Depending on the temperatures and the wind speed (wind chill factor), the clothing can also vary. In extreme temperatures, loose, layered clothing is recommended. The inner layer should be porous and allow for airflow. Other layers should protect against the wind and moisture. Insulated footwear and dry socks are also recommended.

Nutrition and Activity

Nutrition is extremely important in preventing cold-related injuries. Normally, a calorie intake of 3500 cal/day will be adequate, but the work involved in heavy workloads and activities can use 4500–6000 cal/day. Carbohydrates and fats are the preferred sources for energy production. Ideally, the diet should consist of 20% protein, 45% carbohydrates, and 35% fats.

Fluid Replacement

Even in extremely cold climates, dehydration can occur. With the layering of clothing, the body continues to produce sweat. These fluids need to be replaced. On average, a person exposed to extremely cold environments needs to drink at least 2–3 L of water per day. Caffeine-containing drinks increase urine output and increase the risk of dehydration. Consuming warm liquids, such as broth or soups, is desirable to protect the core temperature.

Training and Discipline

Managers and supervisors should be aware that employees need to become acclimated to working in extremely cold environments and should enforce this acclimation process. Physical conditioning assists in preventing cold-related injuries and illnesses. In addition, personnel should be disciplined to maintain adequate personal hygiene, including the frequent changing of undergarments and socks. Training should include the signs, symptoms, and treatment of cold-related injuries.

Susceptible Groups

Greater protection and supervision should be provided for certain groups or individuals, including the fatigued group, the racial group, the geographic group, the previous cold injury group, and those with other injuries and illnesses.

Treatment of Cold-Related Injuries

Initial treatment of cold-related injuries should include the removal of the affected person to a warm environment, loosening of restrictive clothing, and rewarming through blankets and warm environments. Drinking hot/warm fluids to reheat the core body temperature is highly encouraged. Frostbite victims should be seen by a licensed medical provider as soon as possible. Frostbite cases are treated by rapid rewarming in a water bath carefully controlled at 104°F (not to exceed 109°F). Rapid warming should not be continued beyond the time when thawing is complete and should not be instituted if thawing has already occurred. Nonfreezing injuries should not be warmed above 98.6°F. Smoking and the consumption of alcohol should be strictly prohibited.[3]

Key Information to Remember on Thermal Stressors

1. Sources of heat include radiation, convection, conduction, and metabolism.
2. Radiant heat is the amount of thermal radiation between two or more objects.

3. Convective heat is thermal energy transferred by the movement of heated liquid or air.
4. Conductive heat is transferred by the contact of two objects.
5. Metabolic heat is generated from within the body through work.
6. Heat stroke is a medical emergency.
7. Heat-related injuries can be prevented through physical conditioning, fluid replacement, training, and adherence to a work/rest cycle.
8. The equation for an indoor WBGT is WBGT = 0.7 WB + 0.3 GT (no solar load).
9. The equation for outdoor WBGT is WBGT = 0.7 WB + 0.2 GT + 0.1 DB (solar load).
10. Body heat is lost through radiation, conduction, convection, and evaporation.
11. Hypothermia is a reduction of the body's core temperature below 98°F.
12. Frostbite occurs at temperatures below freezing.

References

1. Montana Department of Labor and Industry, Technical Program. 2010. *Thermal Stress: Heat & Cold Stress,* pp. 1–10.
2. U.S. Department of Labor, Occupational Safety and Health Administration. 2010. *Technical Manual (TED 01-00-015).* Available at http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html.
3. Navy Environmental Health Center. 1992. *Prevention and Treatment of Heat and Cold Injuries,* U.S. Navy, Norfolk, VA, Chapter 6.

14

Personal Protective Equipment

On November 15, 2007, the Occupational Safety and Health Administration (OSHA) announced a new rule clarifying employer responsibilities regarding payment for personal protective equipment (PPE). Many OSHA health, safety, maritime, and construction standards require employers to provide their employees with protective equipment, including PPE, when such equipment is necessary to protect employees from job-related injuries, illnesses, and fatalities. These requirements address PPE of many kinds: hard hats, gloves, goggles, safety shoes, safety glasses, welding helmets and goggles, face shields, chemical protective equipment, fall protection equipment, and so forth. The provisions in OSHA standards that require PPE generally state that the employer is to provide such PPE. However, some of these provisions do not specify that the employer is to provide such PPE at no cost to the employee. In this rulemaking, OSHA is requiring employers to pay for the PPE provided, with exceptions for specific items. The rule does not require employers to provide PPE where none has been required before. Instead, the rule merely stipulates that the employer must pay for required PPE, except in limited cases specified in the standard. This final rule became effective on February 13, 2008. The final rule must have been implemented by May 15, 2008.

It is not enough for a Safety Professional just know the regulatory requirements regarding PPE. Today's Safety Professional must have an in-depth knowledge of the uses and limitations of a varied array of PPE. In this chapter, we will look at hard hats, safety glasses and goggles, safety shoes and boots, gloves, fall protection and fall arrest systems, respirators, and other types of personal protective devices. The general industry standards for PPE are outlined in 29 CFR 1910.132–138.

Hazard Assessment

One of the first responsibilities in determining the types of PPE is to determine the hazards present in the work environment. The Safety Professional must conduct a thorough job hazard assessment to determine the specific

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hazards present. The job hazard assessment must be in writing and maintained by the employer. Once the job hazard assessment has been completed, decisions on the types of PPE can be made. An example of a Job Hazard Analysis (JHA) (Table 14.1(a)–(d) can be seen below.

Workers Performing This JHA

No.	NAME	ID NUMBER	CHARGE NUMBER	AREA/COMPANY	SIGNATURE
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Supervisor in Charge

No.	NAME	ID NUMBER	CHARGE NUMBER	AREA/ COMPANY	SIGNATURE
1					

Key Personnel if Lifting

	NAME	SIGNATURE
SPOTTER		
CRANE OPERATOR		
LEAD RIGGER		

TABLE 14.1

(a)–(d): Job Hazard Analysis (JHA)

JOB HAZARD ANALYSIS (JHA) FORM				
Title of Job or Task:			**JHA Number:**	
Date Completed:			**Revision:**	
Person Completing this JHA:			**Person(s) Assisting with this JHA:**	
Location/Facility:				
Recommended Personal Protective Equipment (PPE) Use the personal protective equipment hazard assessment form as a guide — http://www.noao.edu/noaolocal/safety/				
Head Protection	Eye Protection		Hand and Body Protection	Other PPE
Foot Protection	Hearing Protection		Respiratory Protection	
Things to consider				
Do employees know how to do the job?			What are the hazards? Include people and equipment.	
How can injuries or accidents occur?			How can injuries or accidents be prevented?	
Are there obvious unsafe conditions?			Are special tools needed?	
Do people need personal protective equipment?			How would we rescue people if something went wrong?	
Do we have the equipment to rescue?				
Use these designations in the "Hazards Present" column:				
SB—Struck By	CI—Caught In		FB—Fall to Below	CBY—Contacted By
SA—Struck Against	CB—Caught Between		FS—Fall at the Same Level	CO—Caught On
CW—Contact With	O—Overexertion or Repetitive Motion		E—Exposure to Chemicals, Noise, Vibration, Radiation	

(*Continued*)

TABLE 14.1 (CONTINUED)

(a)–(d): Job Hazard Analysis (JHA)

JOB HAZARD ANALYSIS (JHA) FORM		
BASIC JOB STEPS	**1.11 HAZARDS PRESENT IN EACH JOB STEP**	**CORRECT AND SAFE PROCEDURES**
	1.12	
	1.13	
	1.14	
	1.15	
	1.16	
	1.17	
	1.18	
	1.19	
	1.20	

Head Protection (29 CFR 1910.135)[1]

Most often, when we think of occupational head protection, we are referring to "hard hats." The OSHA standard addressing head protection can be located in 29 CFR 1910.135. Protective helmets purchased after July 5, 1994, shall comply with ANSI Z89.1-1986, "American National Standard for Personnel Protection—Protective Headwear for Industrial Workers—Requirements."

Prevention of head injuries is an important factor in every safety program. A recent Bureau of Labor and Statistics survey revealed that most employees having head injuries were not using properly worn head protection.

Head injuries are caused by falling or flying objects or by bumping the head against a fixed object. Head protection, in the form of hard hats, must do two things—resist penetration and absorb the shock of the blow. This is accomplished by making the shell of the hard hat strong enough to resist the impact and by utilizing a shock-absorbing lining composed of headband and crown straps to keep the shell away from the wearer's skull. In addition, protective hats may be designed to protect against electrical shock.

Classification

There are three basic categories or classifications of hard hats, as listed in Table 14.2.

The type of hard hat can be identified by looking inside the shell for the manufacturer, ANSI designation, and class. Helmets are date-stamped by the manufacturer and should be replaced no later than the date recommended by the manufacturer, e.g., 5 years.

TABLE 14.2

Hard Hat Classifications

Item	Standard
Rubber insulating gloves	ASTM D 120-87
Rubber matting for use around electrical apparatus	ASTDM D 178-88 or 178-93
Rubber insulating blankets	ASTDM D 1048-93 or 1048-88A
Rubber insulating hoods	ASTM D 1048-88 or 1049-93
Rubber insulating line hose	ASTM D 1050-90
Rubber insulating sleeves	ASTM D 1051-87

Source: Summary from https://www.osha.gov/sites/default/files/publications/safety_helmet_shib.pdf.

Proper Fit and Wear of Head Protection

Headbands are adjustable in 1/8″ size increments. When the headband is adjusted to the right size, it provides sufficient clearance between the shell and the suspension. There should be a minimum of 1″ to 1 1/4″ clearance between the hard hat and the suspension. This space, known as the safety zone, is extremely important in the absorption of an impact to the hard hat.

Inspection and Maintenance

Manufacturers should be consulted with regard to paint or cleaning materials for their hard hats because some paints and thinners may damage the shell and reduce protection by physically weakening it or negating electrical resistance. A common method of cleaning shells is dipping them in hot water (approximately 140°F) containing a detergent for at least 1 min. Shells should then be scrubbed and rinsed in clear hot water. After rinsing, the shell should be carefully inspected for any signs of damage. All components, shells, suspensions, headbands, sweatbands, and any accessories should be visually inspected daily for signs of dents, cracks, or penetrations and for any other damage that might reduce the degree of safety originally provided. Daily inspections should include the following as a minimum:

- Cracked, torn, frayed, or otherwise deteriorated suspension systems
- Deformed, cracked, or perforated brims or shells
- Flaking, chalking, or loss of surface gloss

Note: Of special note on hard hats is that they have an expiration date. The expiration date is generally accepted to be 5 years. However, replacement is recommended every 2 years. To determine the expiration date, there is a stamped date of manufacture on the underside of the brim of the hat. There will be a number in the middle with an arrow pointing to another number in the outer ring. The middle number will be the year manufactured and the outer number represents the month of manufacture. In Photograph 14.1, the hard hat was manufactured in September of 2018:

Training

Each employee required to wear protective headgear should receive initial and periodic refresher training as needed. Employees should be trained in the following:

- Why head protection is necessary
- How the head protection will protect them
- The limitations of the head protection



PHOTOGRAPH 14.1
Date of manufacture stamp on hard hat brim (Source: Yates, W. David. 2019. *Photograph: Hard Hat Expiration Date*).[2]

- When they must wear the head protection
- How to properly wear the head protection
- How to adjust straps and other parts for a comfortable and effective fit
- How to check for signs of wear

Eye and Face Protect (29 CFR 19101.133)[3]

Suitable eye protection must be provided where there is a potential for injury to the eyes or face from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, potentially injurious light radiation, or a combination of these. Protection must meet the following minimum requirements:

- Provide adequate protection against the particular hazards for which they are designed
- Be reasonably comfortable when worn under the designated conditions
- Fit snugly without interfering with the movements or vision of the wearer
- Be durable
- Be capable of being disinfected
- Be easily cleanable
- Be kept clean and in good repair

Every protection shall be distinctly marked to facilitate identification of the manufacturer. Each affected employee shall use equipment with filter lenses that have a shade number appropriate for the work being performed for protection from injurious light radiation. Table 14.2a and b list the appropriate shade numbers for various work operations.

Each eye, face, or face-and-eye protector is designed for a particular hazard. In selecting the protector, consideration should be given to the kind and degree of hazard, and the protector should be selected on that basis. Where a choice of protectors is given, and the degree of protection required is not an important issue, worker comfort may be a deciding factor.

Fitting

The fitting of goggles and safety spectacles should be done by someone skilled in the procedure. Prescription safety spectacles should be fitted only by qualified optical personnel.

Inspection and Maintenance

It is essential that the lenses of eye protectors be kept clean. Continuous vision through dirty lenses can cause eye strain, often an excuse for not wearing eye protectors. Daily inspection and cleaning of the eye protector with soap and hot water or with a cleaning solution and tissue is strongly recommended. Table 14.3 provides the filter lens protection levels.

Hearing Protection (29 CFR 1910.95)[4]

Exposure to high noise levels can cause hearing loss or impairment. It can create physical and psychological stress. There is no cure for noise-induced

TABLE 14.3

Filter Lenses for Protection against Radiant Energy

(a)

Operation	Electrode Size (1/32 inch Diameter Standard)	Arc Current (A)	Minimum Protective Shade[a]
Shielded metal or	<3/32	<60	7
welding	3/32–5/32	60–160	9
	5/32–8/32	160–250	10
	>8/32	250–500	11
Gas metal arc		<60	7
welding and flux		60–160	10
cored arc welding		160–250	10
		250–500	10
Gas tungsten arc		>50	8
welding		50–150	8
		150–500	10
Air carbon arc cutting	(Light)	<500	10
	(Heavy)	500-1000	10
Plasma arc welding		<20	6
		20–100	8
		100–400	10
		400–800	11
Plasma arc cutting	(Light)b	<300	8
	(Medium)b	300–400	9
	(Heavy)b	400–800	10
Torch brazing			3
Torch soldering			2
Carbon arc welding			14

(b)

Operation	Plate Thickness		Minimum Protective Shade[a]
	in.	mm	
Gas welding:			
Light	<1/8	<3.2	4
Medium	1/8 to 1/2	3.2 to 12/5	5
Heavy	>1/2	>12.7	6
Oxygen cutting:			
Light	<1	<2.5	3
Medium	1 to 6	5 to 150	4
Heavy	>6	>150	5

Source: United States Department of Labor, Occupational Safety and Health Administration (OSHA), *OSHA Technical Bulletin-3077, Personal Protective Equipment*, p. 3.

[a]*As a rule of thumb, start with a shade that is too dark to see the weld zone.*

[b]*These values apply where the actual arc is clearly seen.*

hearing loss; hence, the prevention of excessive noise exposure is the only way to avoid hearing damage. Specifically, designed protection is required, depending on the type of noise encountered and the auditory condition of the employee.

Preformed or molded earplugs should be individually fitted by a professional. Waxed cotton, foam, or fiberglass wool earplugs are self-forming. When properly inserted, they work as well as most molded earplugs.

Some earplugs are disposable, to be used one time and then thrown away. The non-disposable type should be cleaned after each use for proper protection. Plain cotton is ineffective as protection against hazardous noise.

Earmuffs need to make a perfect seal around the ear to be effective. Glasses, long sideburns, long hair, and facial movements, such as chewing, can reduce protection. Special equipment is available for use with glasses or beards.

Hearing Protector Attenuation

The employer is responsible for evaluating hearing protector attenuation for the specific noise environments in which the protector will be used. Hearing protectors must attenuate employee exposure at least to an 8-h time-weighted average of 90 dB as required in 29 CFR 1910.95. For employees who have experienced a standard threshold shift, hearing protectors must attenuate employee exposure to an 8-h time-weighted average of 85 dB or below. The adequacy of hearing protector attenuation shall be reevaluated whenever employee noise exposures increase to the extent that the hearing protectors provided may no longer provide adequate attenuation. The employer shall provide more effective hearing protectors where necessary.

The Environmental Protection Agency requires that manufacturers of hearing protection devices put the noise reduction rating (NRR) on the package. When using the NRR to assess hearing protector adequacy, one of the following methods must be used:

1. When using a dosimeter that is capable of C-weighted measurements:
   a. Obtain the employee's C-weighted dose for the entire work shift and convert to TWA.
   b. Subtract the NRR from the C-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.
2. When using a dosimeter that is not capable of C-weighted measurements, the following method may be used:
   a. Convert the A-weighted dose to TWA.
   b. Subtract 7 dB from the NRR.
   c. Subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

3. When using a sound level meter set to the A-weighting network:
   a. Obtain the employee's A-weighted TWA.
   b. Subtract 7 dB from the NRR and subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the protector.
4. When using a sound level meter set on the C-weighting network:
   a. Obtain a representative sample of the C-weighted sound levels in the employee's environment.
   b. Subtract the NRR from the C-weighted average sound level to obtain the estimated A-weighted TWA under the ear protector.
5. When using area monitoring procedures and a sound level meter set to the A-weighting network:
   a. Obtain a representative sound level for the area in question.
   b. Subtract 7 dB from the NRR and subtract the remainder from the A-weighted sound level for that area.
6. When using area monitoring procedures and a sound level meter set to the C-weighting network:
   a. Obtain a representative sound level for the area in question.
   b. Subtract the NRR from the C-weighted sound level for that area.

Training

The employer shall institute a training program for all employees who are exposed to noise at or above 85 dB and shall ensure employee participation in the program. The training program shall be repeated annually for each employee included in the hearing conservation program. Information provided in the training program shall be updated to be consistent with changes in protective equipment and work practices. The employer shall ensure that each employee is informed of the following:

- The effects of noise on hearing
- The purpose of hearing protectors, the advantages, disadvantages, and attenuation of various types, and instructions on selection, fitting, use and care, and the purpose of audiometric testing procedures

The employer shall make available to affected employees or their representatives copies of the OSHA standard and shall also post a copy in the workplace. The employer shall provide to affected employees any informational materials pertaining to the standard that are supplied to the employer by the Assistant Secretary of Labor. The employer shall provide, upon request, all materials related to the employer's training and education program pertaining to the OSHA standard to the Assistant Secretary of Labor or the OSHA Director.

Respiratory Protection (29 CFR 1910.134)[5]

The OSHA Standard for Respiratory Protection is located in 29 CFR 1910.134. Respirators shall be used in the following circumstances:

- Where exposure levels exceed the permissible exposure limit (PEL), during the period necessary to install or implement feasible engineering and work practice controls
- In those maintenance and repair activities and during those brief or intermittent operations where exposures exceed the PEL and engineering and work practice controls are not feasible or are not required
- In regulated areas
- Where the employer has implemented all feasible engineering and work practice controls, and such controls are not sufficient to reduce exposures to or below the PEL
- In emergencies

Purpose

The purpose of the Respiratory Protection Standard is to control those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors. This shall be accomplished as far as feasible by accepted engineering control measures. When effective engineering control measures are not feasible, or while they are being instituted, appropriate respirators shall be used.

Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee. The employer shall provide the respirators that are applicable and suitable for the purpose intended. The employer shall be responsible for the establishment and maintenance of a respiratory protection program that shall include the requirements of this standard.

Definitions

Air-purifying respirator means a respirator with an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air-purifying element.

Assigned protection factor means the protection factor assigned to the respirator type.

Atmosphere-supplying respirator means a respirator that supplies the respirator user with breathing air from a source independent of the

ambient atmosphere and includes supplied-air respirators and self-contained breathing apparatus units.

Fit test means the use of a protocol to qualitatively or quantitatively evaluate the fit of a respirator on an individual.

Powered air-purifying respirator means an air-purifying respirator that uses a blower to force the ambient air through air-purifying elements to the inlet covering.

Qualitative fit test means a pass/fail test to assess the adequacy of respirator fit that relies on the individual's response to the test agent.

Quantitative fit test means an assessment of the adequacy of respirator fit by numerically measuring the amount of leakage into the respirator.

Self-contained breathing apparatus means an atmosphere-supplying respirator for which the breathing air source is designed to be carried by the user.

Supplied-air respirator or airline respirator means an atmosphere-supplying respirator for which the source of breathing air is not designed to be carried by the user.

Respiratory Protection Program[6]

This standard requires the employer to develop and implement a written respiratory protection program with required worksite-specific procedures and elements for required respirator use. The program must be administered by a suitably trained program administrator. In addition, certain program elements may be required for voluntary use to prevent potential hazards associated with the use of the respirator. The employer shall include in the written program the following information:

- Procedures for selecting respirators for use in the workplace
- Medical evaluations of employees required to use respirators
- Fit testing procedures
- Procedures for proper use of respirators
- Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators
- Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators
- Training required for respirator usage
- Procedures for evaluating the effectiveness of the program

Training and Information

This standard requires the employer to provide effective training to employees who are required to use respirators. The training must be comprehensive,

understandable, and recur annually, and more often, if necessary. Training must ensure that each employee can demonstrate knowledge and understanding of the topic and include

- Why respirator protection is necessary and how improper wearing or use can compromise the protection received?
- Limitations and capabilities of the respirator or cartridge (filter)
- Inspection and maintenance procedures
- Cleaning, disinfecting, and storage procedures
- Proper wear of the respirator
- Retraining shall be administered annually, or when a new process or procedure is implemented that the employee has not been previously trained.

Torso Protection

Many hazards can threaten the torso: heat, splashes from hot metals and liquids, impacts, cuts, acids, radiation, and high-pressure liquids (such as water blasting). A wide variety of protective clothing is available: vests, jackets, aprons, and full body suits. One of the better protective clothing used in protecting workers from high-pressure water blasting is the Water Armor or "Turtle Suit." This suit protects the chest, legs, and arms from glancing blows of up to 40,000 psi. Since many, even in the safety profession, are not familiar with hydro blasting, I have included a photograph of the "Turtle Skin."[6] See Photograph 14.2.

Arm and Hand Protection (29 CFR 1910.138)[8]

When it comes to arm and hand protection, there is no single type that will protect the employee against all hazards. Therefore, it is extremely important to conduct a thorough job hazard analysis to determine the most appropriate arm and hand protection to provide employees. Examples of injuries to arms and hands are burns, cuts, electrical shock, amputation, and absorption of chemicals. There is a wide assortment of gloves, hand pads, sleeves, and wristlets for protection against various hazardous situations. Employers need to determine what hand protection their employees need through a thorough job hazard analysis. The work activities of the employees should



PHOTOGRAPH 14.2
Water armor protective suit (Source: Copyright Warwick Mills, Inc., 301 Turnpike Road, New Ipswich, New Hampshire 03071).[7]

be studied to determine the degree of dexterity required, the duration, frequency, and degree of exposure hazards and the physical stresses that will be applied. It is also important to know the performance characteristics of gloves relative to the specific hazard anticipated, for example, exposure to chemicals, heat, or flames. Gloves' performance characteristics should be assessed by using standard test procedures.

Before purchasing gloves, the employer should request documentation from the manufacturer that the gloves meet the appropriate test standard(s) for the hazard(s) anticipated. For example, for protection against chemical hazards, the toxic properties of the chemical(s) must be determined, particularly the ability of the chemical to pass through the skin and cause systemic effects. The protective devices should be selected to fit the job. For example, some gloves are designed to protect against specific chemical hazards. Employees may need to use gloves (such as wire mesh, leather, and canvas) that have been tested and provide insulation from burns and cuts. The employee should become acquainted with the limitations of the clothing used.

Certain occupations require special protection. For example, electricians need special protection from shocks and burns. Rubber is considered the best material for insulating gloves and sleeves from these hazards. Rubber

TABLE 14.4

ANSI Glove Requirements

Item	Standard
Rubber insulating gloves	ASTM D 120-87
Rubber matting for use around electrical apparatus	ASTDM D 178-88 or 178-93
sRubber insulating blankets	ASTDM D 1048-93 or 1048-88A
Rubber insulating hoods	ASTM D 1048-88 or 1049-93
Rubber insulating line hose	ASTM D 1050-90
Rubber insulating sleeves	ASTM D 1051-87

protective equipment for electrical workers must conform to the requirements established in ANSI as specified in Table 14.4.

Glove Selection Chart

The selection of the appropriate glove can be confusing. Table 14.5 is a glove selection chart based on a summary of various industry charts. It will assist you in selecting the most appropriate personal protection for your employees. The legend for the chart is as follows:

Foot and Leg Protection (29 CFR 1910.136)[9]

According to the BLS survey, most of the workers in selected occupations who suffered foot injuries were not wearing protective footwear. Furthermore, most of their employers did not require them to wear safety boots or shoes. The typical foot injury was caused by objects falling fewer than 4 ft and the median weight was about 65 lb. Most workers were injured while performing their normal job activities at their worksites.

For protection of feet and legs from falling or rolling objects, sharp objects, molten metal, hot surfaces, and wet slippery surfaces, workers should use appropriate footguards, safety shoes or boots, and leggings. Leggings protect the lower leg and feet from molten metal or welding sparks. Safety snaps permit their rapid removal.

Aluminum alloy, fiberglass, galvanized steel, or composite material footguards can be worn over usual work shoes, although they may present the possibility of catching on something and causing workers to trip. Heat-resistant soled shoes protect against hot surfaces like those found in the roofing, paving, and hot metal industries.

Safety shoes or boots should be sturdy and have an impact-resistant toe. In some shoes or boots, metal or composite insoles protect against puncture

TABLE 14.5

Glove Selection Chart

Chemical	Natural Rubber	Neoprene	Butyl Rubber	PVC	Nitrile	Viton
Organic Acids						
Acetic acid	F	G	E	F	P	E
Formic acid	F	G	E	G	F	F
Lactic acid	E	E	E	G	E	E
Maleic acid	G	G	F	G	G	E
Oxalic acid	E	E	E	E	E	E
Inorganic Acids						
Chromic acid up to 70%	P	P	E	G	G	E
Hydrochloric acid up to 37%	G	G	E	G	G	G
Hydrofluoric acid up to 70%	F	F	G	P	P	?
Nitric acid 70+%	?	P	G	?	P	E
Perchloric acid up to 70%	E	E	G	E	E	E
Phosphoric acid up to 70+%	E	E	E	E	E	E
Sulfuric acid 70+%	P	F	E	F	P	F
Alkalis						
Ammonium hydroxide up to 70%	P	G	E	F	G	?
Potassium hydroxide up to 70%	E	E	E	E	E	E
Sodium hydroxide 70+%	E	E	E	E	G	G
Salt Solutions						
Ammonium nitrate	E	E	E	E	E	E
Calcium hypochlorite	P	G	E	E	G	E
Ferric chloride	E	E	E	E	E	E

(*Continued*)

TABLE 14.5 (CONTINUED)

Glove Selection Chart

Chemical	Natural Rubber	Neoprene	Butyl Rubber	PVC	Nitrile	Viton
Mercuric chloride	G	G	E	G	G	E
Potassium cyanide	E	E	E	E	E	E
Potassium dichromate	E	E	E	E	E	E
Potassium permanganate	E	E	?	E	E	?
Sodium cyanide	E	E	E	E	E	E
Sodium thiosulfate	E	E	E	E	E	E
Aromatic Hydrocarbons						
Benzene	P	P	P	P	P	G
Gasoline	P	P	P	P	E	E
Naphthalene	P	P	P	P	E	E
Toluene	P	P	P	P	P	E
Xylene	P	P	P	P	P	E
Aliphatic Hydrocarbons						
Diesel fuel	P	F	P	F	G	E
Hexanes	P	P	P	P	E	E
Kerosene	P	G	P	G	E	E
Naphtha	P	F	P	G	E	E
Pentane	P	P	P	P	G	E
Petroleum ether	P	P	P	F	G	E
Turpentine	P	P	P	P	F	E
Halogenated Hydrocarbons						
Carbon tetrachloride	P	P	P	P	P	E
Chloroform	P	P	P	P	P	E
Methylene chloride	P	P	P	P	F	G
Polychlorinated biphenyls (PCBs)	P	E	E	?	F	E

(*Continued*)

TABLE 14.5 (CONTINUED)

Glove Selection Chart

Chemical	Natural Rubber	Neoprene	Butyl Rubber	PVC	Nitrile	Viton
Perchloroethylene	P	P	P	P	F	E
Trichloroethylene	P	P	P	P	P	E
Esters						
Ethylene acetate	P	P	G	P	P	P
Butyl acetate	P	P	F	P	P	P
Methyl acetate	P	P	E	P	P	P
Isobutyl acrylate	P	P	E	P	P	P
Ethers/Glycols						
Diethyl ether	P	F	P	P	F	P
Ethylene glycol	P	F	E	P	F	E
Isopropyl ether	P	F	P	P	G	P
Propylene glycol	?	G	G	P	P	?
Tetrahydrofuran	P	P	F	P	P	P
Aldehydes						
Acetaldehyde	P	P	E	P	P	P
Acrolein	P	P	E	P	P	P
Benzaldehyde	P	P	E	P	P	G
Butyraldehyde	P	P	E	P	P	P
Formaldehyde	P	F	E	F	E	E
Glutaraldehyde	?	E	E	F	?	E
Ketones						
Acetone	P	P	E	P	P	P
Diisobutyl ketone	P	P	F	P	P	F
Methyl ethyl ketone	P	P	E	P	P	P
Alcohols						

(*Continued*)

TABLE 14.5 (CONTINUED)

Glove Selection Chart

Chemical	Natural Rubber	Neoprene	Butyl Rubber	PVC	Nitrile	Viton
Allyl alcohol	P	P	E	P	E	G
Butyl alcohol	P	G	E	F	G	E
Ethyl alcohol	P	F	G	P	G	E
Isopropyl alcohol	P	G	E	F	E	E
Methyl alcohol	P	P	E	P	P	E
Amines						
Aniline	P	P	E	P	P	F
Ethanolamine	F	E	E	G	E	E
Ethylamine	P	F	E	P	P	P
Methylamine	P	G	E	F	E	E
Triethanolamine	P	P	E	P	E	E
Elements						
Bromine	P	F	P	?	P	E
Chlorine aqueous	?	P	F	?	P	E
Iodine	?	P	G	?	G	E
Mercury	?	E	E	?	E	E
Miscellaneous						
Acetic anhydride	P	F	E	P	P	P
Acetonitrile	P	P	E	P	P	P
Acrylamide	P	P	G	P	F	G
Carbon disulfide	P	P	P	P	P	E
Cresols	P	G	E	?	F	E
Cutting fluid	?	F	?	F	G	?
Dimethyl sulfoxide	P	E	E	P	P	P
Hydraulic oil	?	?	P	F	G	?

(*Continued*)

TABLE 14.5 (CONTINUED)

Glove Selection Chart

Chemical	Natural Rubber	Neoprene	Butyl Rubber	PVC	Nitrile	Viton
Hydrazine	F	E	E	E	E	P
Hydrogen peroxide	E	F	E	G	E	E
Lubricating oil	G	G	?	?	E	G
Malathion	?	G	P	?	G	?
Nitrobenzene	P	P	E	P	P	E
Phenol	P	G	F	P	P	E
Photo solutions	G	E	?	G	E	?
Picric acid	P	F	G	P	F	E
Pyridine	P	P	E	P	P	P

Note: Viton is a registered trademark of DuPont Dow Elastomers.
E—Excellent (breakthrough times >8 h).
G—Good (breakthrough times >4 h).
F—Fair (breakthrough times >1 h).
P—Poor, Not Recommended (breakthrough times <1 h).

wounds. Additional protection, such as metatarsal guards, may be found in some types of footwear. Safety shoes or boots come in a variety of styles and materials, such as leather and rubber boots and oxfords.

Safety footwear is classified according to its ability to meet minimum requirements for both compression and impact tests. These requirements and testing procedures may be found in ANSI standards. Protective footwear purchased after July 5, 1994, must comply with ANSI Z41-1991.

Key Information to Remember on Personal Protective Equipment

1. On November 15, 2007, OSHA implemented a new rule clarifying employer responsibilities regarding payment for PPE. The final rule had a required implementation date of May 15, 2008.
2. The General Industry Standards for PPE are outlined in 29 CFR 1910.132-138.
3. A thorough job hazard assessment is required before issuing PPE.
4. Head Protection (29 CFR 1910.135).
5. There are three classifications of head protection, E (20,000 V), G (2200 V), and C (conductive helmets not intended for protection from electrical conductors).
6. Eye and Face Protection (29 CFR 1910.133).
7. Hearing Protection (29 CFR 1910.95).
8. Respiratory Protection (29 CFR 1910.134).
9. Arm and Hand Protection (29 CFR 1910.138).
10. Foot and Leg Protection (29 CFR 1910.136).

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15

Statistics for the Safety Professional

Statistics are extremely important in the career of the safety professional. We utilize them to report our annual injury and accident rates, calculate failure probability rates, and describe observed or experimental data. For our purposes, the definition of statistics is the study of obtaining meaningful information by analyzing data. These data can come from two different sources. They can come from experiments in a controlled environment or from observations made. Statistics can reduce large sums of data to a manageable form and allow the study and analysis of variance, thus allowing managers to maximize the use of information available in order to form an effective decision. The study and instruction of statistics can take up volumes of text. We will begin the review of statistics by describing descriptive statistics.

Descriptive Statistics

Descriptive statistics are just what the name implies. They are used to describe a set of data. For example, we've all heard polls on the local news that describes the data as 52% of all Americans are opposed to the latest congressional bill plus or minus 3%. What this is stating is that the range of the population that disapproves is 55% to 49%. This is a measure of central tendency.

Mean

The *mean* is also referred to as the "average" or arithmetic mean. For a data set, the mean is the sum of the observations divided by the number of observations. The *mean* is often quoted along with the *standard deviation.* The mean describes the central location of the data, and the standard deviation describes the spread. The mean is represented by the Greek letter (μ), which is mu, *"pronounced moo."* It can also be represented by x. The mathematic representation for calculating the mean is as follows:

$$\mu = \bar{x} = \frac{x_1 + x_2 + \ldots x_n}{n}$$

where

μ and $\bar{x}$ = average or arithmetic mean
x_n = individual data values

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Example

Given that there are four persons in a sample or data set, with the following weights: 125, 1s73, 108, and 211 lb. What is the mean of the weights?

$$\bar{x} = \frac{125 + 173 + 108 + 211}{4}$$

$$\bar{x} = 126.75$$

The average weight in this group is 126.75 or 127 lb.

Mode

The *mode* of a data sample is the variable that occurs most often in the collection. For example, the mode of the sample {1, 3, 6, 6, 6, 6, 7, 7, 12, 12, 17} is 6, since it occurs four times.

Median

The *median* is the middle value in the list of data. To find the median, your numbers have to be listed in numerical order, so you may have to rewrite your list first. If there is no "middle" number, because there is an even set of numbers, then the median is the mean (the usual average) of the middle two values. For example, given the data set {1, 2, 3, 4, 5, 6, 7, 8}, what is the median? The median would lie between 4 and 5; therefore, add 4 + 5 = 9, then divide by 2, giving a product of 4.5. Therefore, the median for the data set is 4.5, which is the central point of the data set.

Note: Mean, mode, and median are all measures of central tendency.

Variance

The *variance* can be described as the degree to which the variables in the data set are spread out. In other words, we would like to know how far away from the mean the variables are. In order to determine the variance from the mean, we would calculate each data point and the mean of the data set. For example, let's assume that you are the corporate safety manager for a corporation having six different and distinct locations. The following information in Table 15.1 shows the number of near misses for the previous year.

To utilize these data in a meaningful way, we cannot simply add the spread and divide by the number of points. By doing this, the positive and negative numbers would simply cancel each other out and be equal to or near zero. Therefore, it is necessary that we square the distances from the mean (average). To do this, we utilize the following equation.

$$\mathrm{Var}(x) = \frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \ldots (x_n - \bar{x})^2}{n}$$

TABLE 15.1

Example Information (Variance)

Company Location	No. of Near Misses (x_i)	($x_i - \mu$)
Illinois	43	11.33
Iowa	26	–5.67
Indiana	31	–0.67
Ohio	28	–3.67
Pennsylvania	38	6.33
Wisconsin	24	–7.67

TABLE 15.2

Example Information—Variance Extension

Company Location	No. of Near Misses (x_i)	($x_i - \mu$)	($x_i - \mu$)²
Illinois	43	11.33	128.37
Iowa	26	–5.67	32.15
Indiana	31	–0.67	0.45
Ohio	28	–3.67	13.47
Pennsylvania	38	6.33	40.07
Wisconsin	24	–7.67	58.83
Total	190	–0.02	273.34
Average (Mean)	31.67	0	45.56

Or written another way:

$$\mathrm{Var}(x) = \sigma^2 = \frac{\sum_{i=1} n(x_i - \bar{x})^2}{n}$$

The variance is represented by the Greek symbol σ^2 and is read as sigma squared.

The variance or sigma squared, in this scenario, is 45.56. The variance is considered to be the spread of the data (Table 15.2). When we take the square root of the variance, it is termed the *standard deviation*, which is represented mathematically by the Greek symbol σ. In this example, the standard deviation or σ is 6.75 or $\sqrt{45.56}$.

The entire process listed above can be written in the following equation:

$$\sigma = \sqrt{\frac{\Sigma(x^2)}{N}}$$

where

$x = \Sigma(x_i - \mu)^2$

N = number of data points

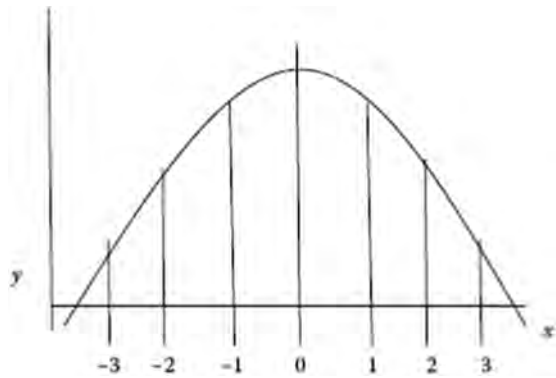


FIGURE 15.1
Graphic representation of standard deviation (Source: Yates, W. David 2024).

The above equation is used whenever you are using data for the entire population. However, when you are taking data from a sample of the population, you should use the following equation:

$$s = \sqrt{\frac{\Sigma\left(x^2\right)}{N-1}}$$

where s = standard deviation or sigma of a sample population.

The only difference in this equation and the previous one is the deduction of 1 in the denominator.

Normal Distribution

Let's now discuss normal distribution. Most of us are familiar with the "bell curve." The bell curve is basically a graph of normal distribution, which has a single peak, and demonstrates that half of the data points are on the left side and half of the data points are on the right side of the curve. The mean lies in the center. The two tails extend indefinitely, never touching the horizontal axis. No matter what the value of the mean and the standard deviation, the area under the curve is 1.00. The variance and standard deviation are measures of the variability of a data set with respect to its mean. The graphic representation is shown in Figure 15.1.

As mentioned previously, the entire bell curve value is 1.00, regardless of the value of the data points. The numbers along the x axis of this graph represent the number of standard deviations in the distribution. Standard deviation values are listed below, which you should commit to memory, as there may be several questions on the examination related to standard deviations:

1. std dev = 68% of the data set
2. std dev = 95.45% of the data set
3. std dev = 99.73 of the data set

Calculating Correlation Coefficient

The *correlation coefficient* is also known as the Product Moment Coefficient or Pearson's Correlation and is described in the following equation:

$$r = \frac{N\Sigma(xy) - (\Sigma x)(\Sigma y)}{\sqrt{\left[N\Sigma\left(x^2\right) - (\Sigma x)^2\right]\left[N\Sigma\left(y^2\right) - \left(\Sigma y^2\right)\right]}}$$

where

r = sample correlation coefficient
N = number of data points
$x = X - \bar{X}$
$y = y - \bar{y}$

This equation is used to determine if there is a correlation between variables. It does not necessarily mean that there is a causation. It simply means that there is a strong possibility that if x is this, then y can be predicted to be that, similar to regression analysis. It indicates the strength of a linear relationship between variables.

Example

Given the following set of data (Table 15.3), calculate the correlation between variable x and variable y.

To insert the data into the equation, and for illustration purposes, let's arrange the needed data into the following format (Table 15.4):

There is a total of six samples (or data points in this sample set). Now that we have the data that we need, we can simply insert it into the equation, as follows:

$$r = \frac{N\Sigma(xy) - (\Sigma x)(\Sigma y)}{\sqrt{\left[N\Sigma\left(x^2\right) - (\Sigma x)^2\right]\left[N\Sigma\left(y^2\right) - \left(\Sigma y^2\right)\right]}},$$

$$r = \frac{6\Sigma(322) - (42)(36)}{\sqrt{\left[6(364) - (42)^2\right]\left[6(286) - (36)^2\right]}}$$

$$r = \frac{420}{\sqrt{[420][420]}}$$

TABLE 15.3

Example Information (Correlation)

x	y
2	1
4	3
6	5
8	7
10	9
12	11

TABLE 15.4

Example Information (Correlation) Extension

x	y	xy	x^2	y^2
2	1	2	4	1
4	3	12	16	9
6	5	30	36	25
8	7	56	64	49
10	9	90	100	81
12	11	132	144	121
Total 42	36	322	364	286
Average 7	6	53.67	60.67	47.67

$$r = \frac{420}{\sqrt{176,400}}$$

$$r = \frac{420}{420}$$

$$r = 1.0$$

The closer the correlation is to positive 1, the more the variables move together in same direction. The closer to negative 1, the more they move in opposite directions. The closer to zero the correlation between two variables are, the less related and more random their movement is.

Spearman Rank Coefficient of Correlation

One method of testing a hypothesis of a correlation between variables is to use the Spearman rank coefficient. The equation is shown mathematically as

$$r_s = 1 - \frac{6\Sigma\left(D^2\right)}{N\left(N^2 - 1\right)}$$

TABLE 15.5

Example Information (Spearman Ranking)

	Plant A	Plant B	Plant C	Plant D	Plant E
Audit score	82.5	93	87.8	77.9	89.8
Injury rate	4.4	2.7	3.8	4.1	2.1

TABLE 15.6

Example Information (Spearman Ranking) Extension

	Audit Score		Injury Rate	
Plant	**Rank**	**Rank**	**D or Δ**	**D^2 or Δ^2**
A	4	5	–1	1
B	1	2	–1	1
C	3	3	0	0
D	5	4	1	1
E	2	1	1	1

where

r_s = Spearman ranking coefficient
D = Δ or difference between the rankings of the two variables
N = number of data points in the set

Example

As the corporate safety manager, you have five companies in your organization. It is your belief that there is a direct correlation between the safety audit scores and injury rates. Given the following data (Table 15.5), calculate the Spearman rank coefficient of correlation.

To obtain the data for the Spearman rank, we need to determine the difference in the rankings, as shown in Table 15.6.

Now, we can insert our data into the equation as follows:

$$r_s = 1 - \frac{6(4)}{5\left(5^2 - 1\right)}$$

$$r_s = 1 - \frac{24}{5(25-1)}$$

$$r_s = 1 - \frac{24}{120}$$

$$r_s = 1 - 0.2$$

$$r_s = 0.8$$

The Spearman rank is a reflection of correlation between two sets of numbers. The distance from 1 implies the correlation between the two variables, either a weak or strong correlation. If the number is positive, it may indicate a stronger correlation, whereas a negative number may imply a weaker correlation.

Calculating the *t* Test for Comparing Means

The *t* test is used to calculate the significance of observed differences between the means of two samples. It can be used to determine if there is a difference between two population parameters. Additionally, it can be used in situations where one of the conditions, the population standard deviation, is not known and the sample size is $\leq$30. It is generally used with scalar variables, such as length and width. The null hypothesis is that there are no significant differences between the means. To do this, we use the following equation:

$$t = \frac{\overline{X} - \mu}{s}\sqrt{N-1} = \frac{\overline{x} - \mu}{\hat{s}}$$

Example

A manufacturing process requires that a flange be manufactured to 25 cm. The quality control department collected five samples of the flange with the following results: 24.33 cm, 25.2 cm, 24.98 cm, 24.79 cm, and 24.88 cm. What is the *t*-statistic value?

The first step is to calculate the mean of the samples collected. The mean is calculated as follows:

$$\textbf{Mean} = \frac{24.33 + 25.2 + 24.98 + 24.79 + 24.88}{5}$$

$$\textbf{Mean} = \frac{124.18}{5}$$

$$\textbf{Mean} = \textbf{24.84 cm}$$

From the mean, calculate the standard deviation, which is 0.3215.

$$t = \frac{24.85 - 25}{0.3215}\sqrt{5-1}$$

$$\boldsymbol{t} = -0.9953$$

Chi-Square (χ^2) Statistic

The *chi-square* (χ^2) *statistic* is useful in comparing observed distributions to theoretical ones. To calculate the *chi-square* (χ^2) *test,* we use the following equation:

$$\chi^2 = \sum_{j=1}^{k} \frac{\left(o_j - e_j\right)^2}{e_j}$$

where
o = observed data
e =expected data

Example

A review of 150 death certificates was conducted in a local community. Of the 150 deaths, 22 of the persons died of cancer, where 28.3 were expected under normal conditions. The rest died of other causes where 121.7 would normally be expected. What is the χ^2 value?

Solution

$$\chi^2 = \Sigma \frac{(22 - 28.3)^2}{28.3} + \frac{(128 - 121.7)^2}{121.7}$$

$$\chi^2 = \Sigma \frac{39.69}{28.3} + \frac{39.69}{121.7}$$

$$\chi^2 = 1.402 + 0.326$$

$$\chi^2 = 1.728$$

Before explaining what the χ^2 value represents, it is first necessary to discuss *degrees of freedom* and *p values.*

Degrees of Freedom

Degrees of freedom can be described as the number of scores that are free to vary. For example, in the above scenario, you have two possible outcomes. One outcome is that employees were treated for cancer or they were treated

for other illnesses. If an employee was treated for cancer, then they were included in the observed category. In summary, in this scenario, there is only one degree of freedom.

Note: In most studies, the degree of freedom is normally computed by the number of observed minus 1.

p Values

The *p* value is defined as the probability of obtaining a result as extreme as the one observed, assuming that the null hypothesis is true. The *lower* the *p* value, the *less* likely the result, assuming the null hypothesis, so the *more* "significant" the result. A *p* value of 0.05 represents that there is a 5% chance of an outcome that extreme, given the null hypothesis.

Note: Now that we have explained the degree of freedom and *p* value, we can take the χ^2 value from our example above (which is 1.128) and using the Chi-Square Distribution table, which can be found on the Internet or other published sources, we determine the *p* value for one degree of freedom to be between 0.2 and 0.1, but closer to 0.2. A *p* value of approximately 0.2 means that the data are statistically significant at the $p = 0.2$ level, or there is only a probability of 0.2 that the data are NOT significant.

Permutations and Combinations

There is no easy definition of permutation or combination, in regard to mathematics. Therefore, it is necessary that we explain the difference between the two. To illustrate what each are, an example of each is listed below:

Combination: A group of data or items where an order doesn't matter. For example: your meal consists of chicken, salad, bread, and vegetable. Bread, salad, vegetable, and chicken are still your meal. In other words, no matter what order you place the items in, it is still the original meal.

Permutation: A group of data or items where an order does matter. For example: the numbers to a combination lock are 5-8-6, which is not the same as 8-6–5. In this example, the order matters. A permutation is an ordered combination.

Note: If the order doesn't matter, it is a Combination. If the order matters, it is a Permutation.

There are two types of permutations. The first type is when repetition is allowed. For example, the lock mentioned above may have a data set of 4-4-4. The second type is when no repetition is allowed, as in describing the first three in an automobile race.

Permutations with Repetition

To calculate permutations with repetition, simply multiply the data points as described in the equation below:

$$n^r = n \times n \times \ldots n$$

where

n^r = permutation when repetition is allowed
n = the number of possibilities to choose from

In this example, there are 10 possibilities to choose (0, 1, 2, 3, … 9) from and you are selecting 3 of them; therefore, the permutation for this data set is solved mathematically as follows:

$$n^r = 10 \times 10 \times 10 = 10^3 = 1000 \text{ permutations.}$$

As you can see, calculating permutations with repetition is quite simple.

Permutations without Repetition

Calculating permutations without repetition is slightly more complicated. To calculate the permutation for the number of the combination lock mentioned previously where the numbers are 5-8-6, which are required to be in a specific order, we would use the following equation:

$$P_k^n = \frac{n!}{(n-k)!}$$

where

P_k^n = permutation
n = the number of data points to choose from
k = the number of data points you choose

Example

From the scenario above, you have 10 numbers to choose from (0, 1, 2 … 9), and of these 10 numbers, you are actually choosing 3 of them (5-8-6). How many permutations can be present in this scenario?

$$P_3^{10} = \frac{10!}{10-3!}$$

$$P_3^{10} = \frac{3,628,800}{5040}$$

$$P_3^{10} = 720$$

In this scenario, there are 720 permutations that can result.

Combinations

When calculating combinations, we use the following equation:

$$C_k^n = \frac{n!}{k!(n-k!)}$$

where

C_k^n = combination
n = the number of data points to choose from
k = the number of data points you choose

Example

There are 10 plants in a corporation. Of these 10 plants, 4 are to be picked, at random (order doesn't matter), to be issued new safety equipment for evaluation. How many different combinations of plant representation are possible to receive the safety equipment?

$$C_4^{10} = \frac{10!}{4!(10-4)!}$$

$$C_4^{10} = \frac{3,268,800}{4!(6)!}$$

$$C_4^{10} = \frac{3,628,800}{24(720)}$$

$$C_4^{10} = \frac{3,628,800}{17,280}$$

$$C_4^{10} = 210$$

In this scenario, there are a possible 210 combinations of plants that can be selected to receive the new safety equipment.

Z-Score

In statistics, a *standard score* indicates how many standard deviations an observation or datum is above or below the mean. It is a dimensionless quantity derived by subtracting the population mean from an individual raw score and then dividing the difference by the population standard deviation. This conversion process is called *standardizing* or *normalizing;* however, "normalizing" can refer to many types of ratios; see normalization (statistics) for more.

The standard deviation is the unit of measurement of the *z*-score. It allows comparison of observations from different normal distributions, which is done frequently in research.

Standard scores are also called *z-values, z-scores, normal scores,* and *standardized variables;* the use of "Z" is because the normal distribution is also known as the "Z distribution." They are most frequently used to compare a sample to a standard normal deviate (standard normal distribution, with $\mu = 0$ and $\sigma = 1$), although they can be defined without assumptions of normality.

The *z*-score is *only* defined if one knows the population parameters, as in standardized testing; if one only has a sample set, then the analogous computation with sample mean and sample standard deviation yields the Student's *t* statistic. *Z*-scores can be calculated using the following equation:

$$z = \frac{\chi^2 - \mu}{\sigma}$$

where

z = score (unitless)
χ^2 = chi-square value
σ = standard deviation

Example

You just completed a statistical review of your safety training program, which showed a mean score on the final examination of 79.2% and a standard deviation of 8.3. One student scored 82.6%. Assuming a standard distribution, how many students scored higher than this one student on the exam?

Solution

$$z = \frac{82.6 - 79.2}{8.3}$$

$$z = \frac{3.4}{8.3}$$

$$z = 0.41$$



Probability content from −00 to Z

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

FIGURE 15.2
Table of normal distribution. This table is public domain and produced by William Knight, *APL Program*. Available at http://www.math.unb.ca/~knight/utility/NormTble.htm.

Now refer to Figure 15.2 s^1 and determine the area under the curve associated with a z-score of 0.41. Begin with 0.4 under the z column, then go over to Column 0.01 and the area beneath that represents a z-score of 0.41 is 0.6591.

To calculate the total number of persons taking the exam that scored higher than 82.6%, we subtract the total area from the whole as follows: 1 − 0.6591 = 0.3409; 0.3409 × 100 = 34.09%. Therefore, 34.09% of people taking the examination scored higher than 82.6%.

Coefficient of Determination and Coefficient of Correlation

In statistics, the *coefficient of determination*, r^2, is used in the context of statistical models whose main purpose is the prediction of future outcomes on the basis of other related information. It is the proportion of variability in a data set that is accounted for by the statistical model. The coefficient of determination can be calculated using the following equation:

$$r^2 = \frac{\text{explained variation}}{\text{total variation}}$$

The coefficient of correlation can be calculated using the coefficient of determination, as follows:

Example

Your company president believes that unsafe behaviors lead to accidents and injuries. As a result, he requested that you, as the safety manager, conduct a study. Your study reveals the following data. In your study, you recorded total variations of 53.8 and explained variations of 39.2. Calculate the r^2 value and r value.

Solution

$$r^2 = \frac{39.2}{53.8}$$

$$r^2 = 0.7286$$

Now calculate the r value (correlation value):

$$r = \sqrt{0.7286}$$

$$r = 0.8536$$

An r value close to 1 indicates a strong linear relationship. A value closer to 0 indicates a weak linear relationship.

Reliability

Component Reliability

Reliability is the ability of a system or component to perform its required functions under stated conditions for a specified period. It is often reported

as a probability. To calculate the reliability of a component, use the following equation:

$$R(t) = e^{-\lambda t}$$

where
$R(t)$ = reliability
t = time in which reliability is measured

$$\lambda = \frac{\#\text{ of failures}}{\#\text{ of time units exposed}}$$

Example

An inline valve has a failure rate of 2×10^{-6} failures per hour, what is its reliability in an operation period of 5000 h?

Insert the data into the equation as follows:

$$R_{5000h} = e^{-2\times10^{-6}(5000h)}$$

$$R_{5000\text{h}} = e^{-0.01}$$

$$R_{5000\text{h}} = 0.99$$

Based on the outcome of this equation, the component has a failure probability rate of 0.01 failures per 5000 h.

Probability of Failure (Component)

The probability that a component will fail in a projected time is equal to 1 minus the reliability of that period. Written mathematically, this statement is as follows:

$$\boldsymbol{P}_{\mathbf{f}} = 1 - \boldsymbol{R}_{\mathbf{t}}$$

Example

Using the result from the reliability equation above, we insert the given data as follows:

$$P_{\text{f}} = 1 - 0.99$$

$$P_{\text{f}} = 0.01$$

As previously stated, this component has a failure probability rate of 0.01 failures per 5000 h. This equation is used primarily for individual components within a system.

System Reliability

Mechanical and electrical systems consist of numerous individual components. The reliability of the system depends on how the components are arranged and upon their failure rates.

Series Reliability

If the components are arranged in such a manner that a failure of any individual component results in the entire system failing, then it is known as a *series system.* Use the following equation to calculate the overall system series reliability:

$$R_{\text{system}} = R_1 \times R_2 \times \ldots \times R_n$$

Note: This equation is not listed on the BCSP exam reference sheet but is useful in calculating the overall system failure rates.

Example

You are asked to calculate the reliability of a system with six individual components. The reliability of the individual components is 0.98, 0.99, 0.98, 0.97, 0.97, and 0.98. What is the system reliability?

$$R_{\text{system}} = 0.98 \times 0.99 \times 0.98 \times 0.97 \times 0.97 \times 0.98$$

$$R_{\text{system}} = 0.88$$

As you can see from the outcome of the calculation, the individual component reliability is relatively high, but when put in a parallel arrangement, the overall system reliability is reduced.

Parallel reliability

A system where one individual component can fail, and the system will still be functional is known as a parallel system. To calculate the reliability of a parallel system, use the following equation:

$$R_{\text{system}} = 1 - (1 - R_1)(1 - R_2)\ldots(1 - R_n)$$

Example

Given the same data provided in the series example, calculate the system reliability of the six components acting as a parallel system.

$$R_{\text{system}} = 1 - (1 - 0.98)(1 - 0.99)(1 - 0.98)(1 - 0.97)(1 - 0.97)(1 - 0.98)$$

$$R_{\text{system}} = 1 - (0.02)(0.01)(0.02)(0.03)(0.03)(0.02)$$

$$R_{\text{system}} = 1 - 7.2^{-11}$$

$$R_{\text{system}} = 0.9999999996 \text{ or } 1.0$$

As you can see, the arrangement of the individual components is extremely important. Note that while the individual components have relatively high reliabilities, their arrangement increases the reliability of the system.

Probability of Failure (System)

When calculating the probability of failure of a system, use the following equation:

$$P_{\text{f}} = (1 - P_{\text{s}})$$

where
P_f = probability of failure
P_{s} = probability of success or reliability of the system

Example

The reliability of a system is 0.88. What is the probability of failure rate for that system?

$$P_{\text{f}} = (1 - 0.88)$$

$$P_{\text{f}} = 0.12$$

Key Information to Remember on Statistics for the Safety Professional

1. The *mean* is also referred to as the "average" or arithmetic mean. For a data set, the mean is the sum of the observations divided by the number of observations.
2. The *mode* of a data sample is the variable that occurs most often in the collection.
3. The *median* is the middle value in the list of data.

4. The *variance* can be described as the degree to which the variables in the data set are spread out. In other words, we would like to know how far away from the mean the variables are.
5. 1 std dev = 68% of the data set
6. 2 std dev = 95.45% of the data set
7. 3 std dev = 99.73 of the data set
8. The *p* value is defined as the probability of obtaining a result as extreme as the one observed, assuming that the null hypothesis is true.
9. *Reliability* is the ability of a system or component to perform its required functions under stated conditions for a specified period. It is often reported as a probability.

Reference

1. Knight, W. 2010. *APL Program.* Available at http://www.math.unb.ca/~knight/utility/NormTble.htm.

16

Electrical Safety

The average person is aware that electricity can be dangerous if not used or worked on properly, using safe work practices. Occupational hazards of electricity are increased, especially on construction sites, where there are portable power tools, sometimes cluttered work sites, and the fast pace of production. Injuries resulting from electricity include electrocution (death from electrical shock), electrical shock, falls, and burns, which if left untreated can become infected Chapter 14 provides an overview on the basics of electricity and the basic practices to prevent injuries related to it. The topics covered in this chapter include voltage; current; resistancep series and parallel circuits; direct and alternating currents; capacitance; inductance; and the injuries that can result from exposure to electricity. The chapter also discusses how to protect facilities and employees from fires caused by improper or inadequate wiring.

Electricity Basics

Electricity flows in a similar fashion to water flowing through a garden hose. Water moves through the hose from an area of high pressure to an area of low pressure. Electricity operates in much the same way. Electrical currents move from high voltage to low voltage (area of least resistance). To understand electricity, three important concepts must be mastered, which include voltage, current, and resistance.

Voltage

Voltage between two points is basically a term used to describe the total amount of electrical force (energy) that drives the current between the two points. Voltage is measured in terms of volts (V).

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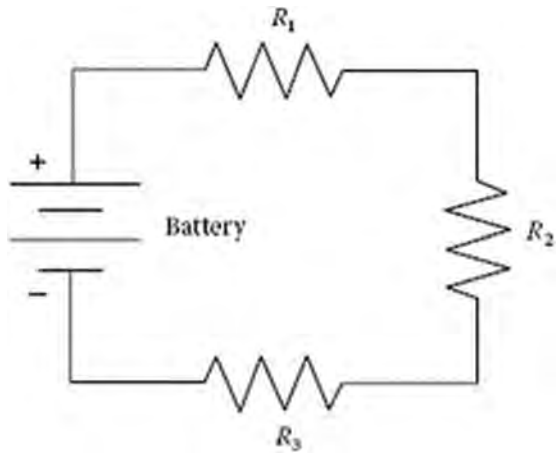


FIGURE 16.1
Illustration of a simple series circuit (Source: Yates, W. David 2024).

Current

The electrical current is the flow of electric charge or the rate of flow of electric charge. Current, denoted by the letter *I*, is measured in amperes (A).

Resistance

Electrical resistance is a measure of the opposition to the flow of steady electrical current. Resistance (*R*) is measured in ohms (Ω).

Series and Parallel Circuits

Series Circuits

Components connected in series are connected along a single path; thus, the same current flows through all of the components. A simple series circuit is illustrated in Figure 16.1.

Parallel Circuits

In a parallel circuit, the electrical current to each element in the circuit is separate; hence, if one element was to burn out, the other resistors would still have power. Also, if you add an extra element, the other elements will still have the same amount of voltage as before. If you remove an element, the other elements will also still have the same amount of voltage as before. A simple parallel circuit is illustrated in Figure 16.2.

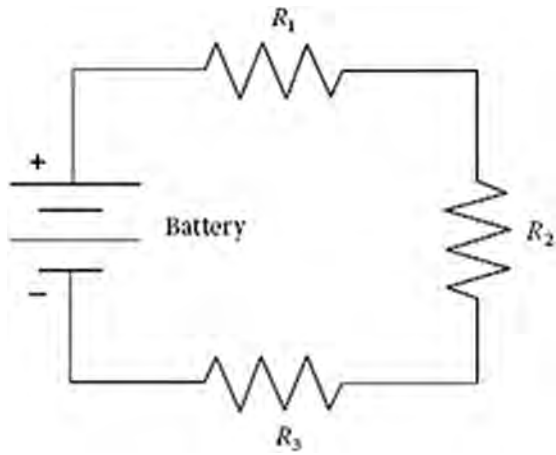


FIGURE 16.2
Illustration of a simple parallel circuit (Source: Yates, W. David 2024).

Direct and Alternating Currents

Direct Currents

Direct current (DC) is the unidirectional flow of an electric charge. In other words, the current flows through the circuit in the same direction at all times.

Alternating Currents

In alternating currents (AC), the flow of electric charge periodically reverses direction. The current flow passes through a regular succession of changing positive and negative values by periodically reverting its direction of flow. The total positive and negative values of current are equal.

Calculating Values of Voltage, Current, and Resistance (Ohm's Laws)

Calculating Voltage in DC Circuits

The voltage of a circuit can be calculated using the following equation:

$$V = IR$$

where
V = volts
I = current (A)
R = resistance of the circuit (Ω)

For example, calculate the voltage for a DC circuit with the following data: (I = 0.5 A, 5 Ω)

$$V = (0.5\text{A})(5\Omega)$$

$$V = 2.5\text{V}$$

Calculating Voltage in AC Circuits

To calculate the voltage in AC circuits, use the following equation (Figure 16.3).

$$V = \sqrt{\frac{PI}{\cos\phi}}$$

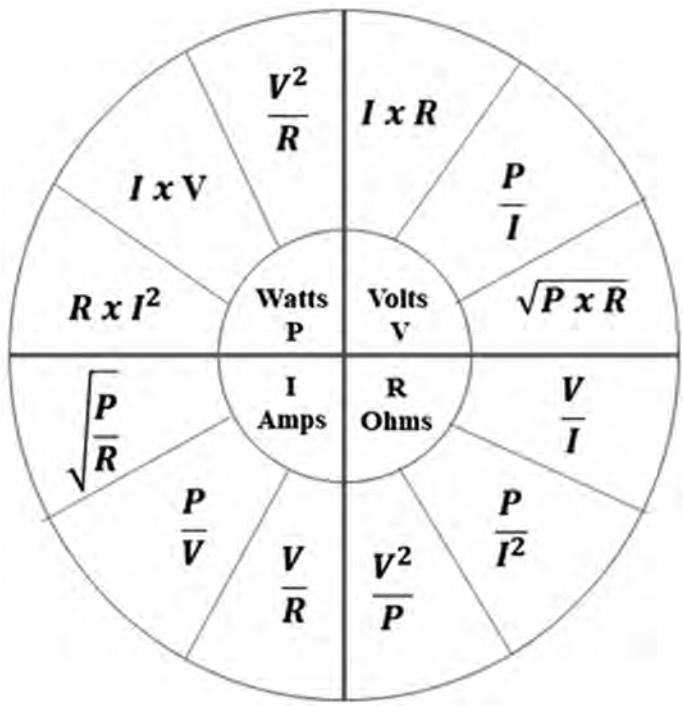


FIGURE 16.3
Electrical calculations (Source: Yates, W. David 2024). (http: shutterstock.com/catalog/licenses) Royalty-free stock illustration ID: 1884531286.

where
V = voltage
I = impedance (Ω)
ϕ = the phase angle in degrees by which current lags voltage in an inductive circuit or leads in a captive circuit
P = true power (W)

By way of example, calculate the Voltage for a circuit that is 5,000 W with a resistance (impedance) of 3Ω, with an angle of lag is 25 degrees.

$$V = \sqrt{\frac{(5{,}000W)(3\&)}{\cos 25}}$$

$$V = \sqrt{\frac{(5{,}000W)(3\&)}{0.9063}}$$

$$V = \sqrt{\frac{(15{,}000)}{0.9063}}$$

$$V = 129 volts$$

Calculating Power in DC Circuits

To calculate power in DC circuits, apply the following equation:

$$P = VI$$

where
P = power (W)
V = volts
I = current (A)

Calculating Power in AC Circuits

To calculate power in AC circuits, apply the following equation:

$$P = \frac{V^2 \times \cos\phi}{R(\text{impedance})}$$

where
P = power (W)
V = volts
R = resistance (more specifically when discussing ACs, it is referred to as impedance) (Ω)
ϕ = the phase angle in degrees by which current lags voltage in an inductive circuit or leads in a captive circuit

Calculating Resistance in DC Circuits

To calculate the resistance in DC circuits, use the following equation:

$$R = \rho \frac{L}{A}$$

where
R = resistance of the circuit (Ω)
ρ = Rho (resistivity of the metal) (intrinsic ability to resist the flow of electricity)
L = length (m)
A = cross-sectional area in square meters

Calculating Resistance in AC Circuits

The formula for calculating resistance in AC circuits is shown as

$$I = \frac{V}{A}$$

where
I = impedance (Ω)
V = volts
A = amperes

Resistors

Resistors are elements of electrical and electronic systems that are designed to intentionally resist the flow of electrical current through the system at a known measurement. The higher the value of resistance (measured in ohms), the lower the current will be. The primary characteristics of a resistor are the resistance, the tolerance, maximum working voltage, and the power rating.

Calculating the Resistance in a Series Circuit

To calculate the total resistance in a series circuit, use the following equation:

$$R_{\text{series}} = R_1 + R_2 + \ldots R_n$$

where
R_{series}= total resistance (Ω)
R_x = resistance of individual resistor (Ω)

For example, you have three resistors in series, valued respectively at 2 Ω, 4 Ω, and 6 Ω. The total resistance of the circuit is calculated as follows:

$$R_{\text{series}} = 2\Omega + 4\Omega + 6\Omega$$

$$R_{\text{series}} = 12\Omega$$

Calculating the Resistance in a Parallel Circuit

In a parallel circuit, the total resistance is calculated as follows:

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_n}$$

where

R_{parallel} = total resistance (Ω) in parallel
R_n = resistance of individual resistors (Ω)

For example, you have the same resistors as in the series circuit, but now they are in parallel. The values of each resistor are 2 Ω, 4 Ω, and 6 Ω. What is the total resistance of this parallel circuit?

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{2\Omega} + \frac{1}{4\Omega} + \frac{1}{6\Omega}$$

$$\frac{1}{R_{\text{parallel}}} = 0.5\Omega + 0.25\Omega + 0.17\Omega$$

$$\frac{1}{R_{\text{parallel}}} = 0.92\Omega$$

$$R_{\text{parallel}} = 1.09\Omega$$

Thus, the total resistance for this parallel circuit is 1.09 Ω.

Capacitors

A capacitor or condenser is a passive electronic component consisting of a pair of conductors separated by a dielectric (insulator). When a potential difference (voltage) exists across the conductors, an electric field is present

in the dielectric. This field stores energy and produces a mechanical force between the conductors. Capacitor values are measured in farads (F).

Calculating Capacitance in a Series Circuit

To calculate the total capacitance in a series circuit, use the following equation:

$$\frac{1}{C_{\text{series}}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots \frac{1}{C_n}$$

where

C_{series} = total capacitance in a series circuit (F)
C_n = individual capacitor value (F)

For example, three capacitors with individual values of 0.1 μF, 0.2 μF, and 0.3 μF are aligned in series. What is the total capacitance?

$$\frac{1}{C_{\text{series}}} = \frac{1}{0.1\mu\text{F}} + \frac{1}{0.2\mu\text{F}} + \frac{1}{0.3\mu\text{F}}$$

$$\frac{1}{C_{\text{series}}} = 10\mu\text{F} + 5\mu\text{F} + 3.33\mu\text{F}$$

$$\frac{1}{C_{\text{series}}} = 18.33\mu\text{F}$$

$$C_{\text{series}} = 0.055\mu\text{F}$$

The total capacitance for this series circuit is 0.055 μF. One important point to remember about capacitors connected in series is that the total capacitance will always be less than the value of the smallest capacitor value. In this particular case, the total value is 0.055 μF, which is less than 0.1 μF (smallest capacitor).

Calculating Capacitance in a Parallel Circuit

When calculating the capacitance of a parallel circuit, use the following equation:

$$C_{\text{parallel}} = C_1 + C_2 + \ldots C_n$$

where
$C_{parallel}$ = total capacitance in a parallel circuit (F)
C_n = individual capacitor value (F)

For example, using the values from the capacitors in the series circuit equation (0.1, 0.2, and 0.3 μF), calculate the capacitance in a parallel circuit.

$$C_{parallel} = 0.1\mu F + 0.2\mu F + 0.3\mu F$$

$$= 0.6\mu F$$

Inductors

An *inductor* or a *reactor* is a passive electrical component that can store energy in a magnetic field created by the electric current passing through it. An inductor's ability to store magnetic energy is measured by its inductance, in units of henries (H). Typically, an inductor is a conducting wire shaped as a coil, the loops helping to create a strong magnetic field inside the coil owing to Faraday's law of induction. Inductors are one of the basic electronic components used in electronics where current and voltage change with time, because of the ability of inductors to delay and reshape ACs.

Calculating Inductance in a Series Circuit

To calculate the inductance in a series circuit, use the following equation:

$$L_{series} = L_1 + L_2 + \ldots L_n$$

where
L_{series} = the total series circuit inductance (H)
L_n = individual inductor value (H)

For example, there are three inductors in series, with the individual values of 0.35 μH, 0.4 μH, and 0.5 μH. What is the total inductance of the series circuit?

$$L_{series} = 0.35\mu H + 0.4\mu H + 0.5\mu H$$

$$L_{series} = 1.25\mu H$$

Calculating Inductance in a Parallel Circuit

To calculate the inductance in a parallel circuit, use the following equation:

$$\frac{1}{L_{\text{parallel}}} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots \frac{1}{L_n}$$

where

L_{parallel} = the total parallel circuit inductance (H)
L_n = individual inductor value (H)

Using the values described in the series circuit, calculate the total inductance if the inductors were placed in a parallel circuit.

$$\frac{1}{L_{\text{series}}} = \frac{1}{0.35\mu\text{H}} + \frac{1}{0.4\mu\text{H}} + \frac{1}{0.5\mu\text{H}},$$

$$\frac{1}{L_{\text{series}}} = 2.86\mu\text{H} + 2.5\mu\text{H} + 2\mu\text{H}$$

$$\frac{1}{L_{\text{series}}} = 7.36\mu\text{H}$$

$$L_{\text{series}} = 0.14\mu\text{H}$$

Electrical Shock Hazard

An electrical shock is received when electrical current passes through the body. Current will pass through the body in a variety of situations. Whenever two wires are at different voltages, current will pass between them if they are connected. The body can connect the wires if you touch both of them at the same time, and the current will then pass through your body. For example, in the normal household wiring, the black and red wires are at 120 V, while the white wire is at 0 V (since it is connected to ground). If you come into contact with an energized black wire and are also in contact with the neutral white wire, current will pass through your body, and thus, you will receive an electrical shock.[1] Moisture (sweat, pools of standing water) increases the risk of receiving an electrical shock.

You can also receive an electrical shock even if you're not in contact with an electrical ground. For example, contact with both live wires of a 240-V cable will deliver a shock. The primary reason for this type of electrical shock is that one wire may be at 120 V and the other at –120 V (a difference

TABLE 16.1

Effects of Electrical Currents on the Human Body

Current	Reaction
<1 mA	Generally, not perceptible.
1 mA	Faint tingle.
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go. Strong voluntary reactions can lead to other injuries.
6–25 mA (women) 9–20 mA (men)	Painful shock, loss of muscular control. The freezing current (let go) range. Individual cannot let go but can be thrown away from the circuit if extensor muscles are stimulated.
50–150 mA	Extreme pain, respiratory arrest, severe muscular contractions. Death is possible.
1000–4300 mA	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death likely.
10,000 mA	Cardiac arrest and severe burns occur. Death is probable.
15,000 mA	Lowest overcurrent at which a typical fuse or circuit breaker opens a current.

Source: National Institute of Occupational Safety and Health, 2009. *Electrical Safety, Safety and Health for Electrical Trades, Student Manual,* Department of Health and Human Services, Centers for Disease Control, NIOSH, Cincinnati, OH, https://www.cdc.gov/niosh/docs/2009-113/pdfs/2009-113.pdf, p. 7.

of 240 V). Electrical shocks can be caused by electrical components that are not properly grounded.[2]

The severity of injury from an electrical shock depends on the amount of electrical current and the length of time the current passes through the body. For example, 1/10 of an ampere of electricity going through the body for just 2 s is enough to cause death. The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 mA. Currents greater than 75 mA cause ventricular fibrillation. This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim. Heart paralysis occurs at 4 A, which means the heart does not pump at all. Tissue is burned with currents greater than 5 A.[3] Table 16.1 shows the effects of electrical current on the human body.[4]

Burns Caused by Electricity

The most common shock-related, nonfatal injury from electricity is burns. Burns caused by electricity may be of three types: electrical burns, arc burns, and thermal contact burns. Electrical burns can result when a person touches electrical wiring or equipment that is used or maintained improperly. Typically, such burns occur on the hands. Electrical burns are one of the

most serious injuries you can receive and need to be given immediate medical attention. Additionally, clothing may catch fire and a thermal burn may result from the heat of the fire.[5]

Arc Blasts

Arc blasts occur when powerful, high-amperage currents arc through the air. Arcing is the luminous electrical discharge that occurs when high voltages exist across a gap between conductors and current travels through the air. This situation is often caused by equipment failure owing to abuse or fatigue. Temperatures as high as 35,000°F have been reached in arc blasts. There are three primary hazards associated with an air blast.

1. Arcing gives off thermal radiation (heat) and intense light, which can cause burns.
2. A high-voltage arc can produce a considerable pressure wave blast.
3. A high-voltage arc can also cause many of the copper and aluminum components in electrical equipment to melt. These droplets of molten metal can be blasted great distances by the pressure wave.[6]

Electrical Fires

Electricity is one of the most common causes of fires and thermal burns in homes and workplaces. Defective or misused electrical equipment is a major cause of electrical fires. If there is a small electrical fire, use only a Class C or multipurpose (ABC) fire extinguisher.[7]

Controlling Electrical Hazards

Electrical accidents are caused by a combination of three factors:

- Unsafe equipment or installation
- Workplaces made unsafe by the environment
- Unsafe work practices

Exposed Electrical Parts

Electrical hazards exist when wires or other electrical parts are exposed. Wires and parts can be exposed if a cover is removed from a wiring or

breaker box. The overhead wires coming into a home may be exposed. Electrical terminals in motors, appliances, and electronic equipment may be exposed. Older equipment may have exposed electrical parts. If you contact exposed live electrical parts, you will be shocked.[8]

Overhead Power Lines

Overhead power lines are not usually insulated. Some examples of equipment that come into contact with power lines include cranes, ladders, scaffolding, backhoes, scissor lifts, raised dump truck beds, and aluminum paint rollers. To control the hazards presented by overhead power lines,

- A worker can stay at least 10 ft away.
- A worker can post warning signs.
- A worker can assume that lines are energized.
- A worker can use wood or fiberglass ladders, not metal.
- Power line workers need special training and personal protective equipment.

Inadequate Wiring

An electrical hazard exists when the wire is too small a gauge for the current it will carry. Normally, the circuit breaker in a circuit is matched to the wire size. However, in older wiring, branch lines to permanent ceiling light fixtures could be wired with a small gauge than the supply cable. When you use an extension cord, the size of the wire you are placing into the circuit may be too small for the equipment. The circuit breaker could be the right size for the circuit but not right for the smaller-gauge extension cord. A tool plugged into the extension cord may use more current than the cord can handle without tripping the circuit breaker. The wire will overheat and could cause a fire.[9]

Defective or Damaged Cords and Wires

All too often on construction sites, cords become damaged through aging, door or window edges, staples or fastenings, abrasion from adjacent materials, or activity in the area. Improper use of these cords can cause shocks, burns, or fires. To control the hazards associated with damaged or defective cords or wires, use one or more of the following control methods:

- Insulate live wires.
- Inspect all cords and wires before each use.
- Use only cords that are 3-wire type.

- Use only cords marked for hard or extra-hard usage.
- Use only cords, connection devices, and fitting equipped with strain relief.
- Remove cords by pulling on the plugs, not the cord.
- Cords not marked for hard or extra-hard use, or which have been modified or damaged, must be taken out of service immediately.

Use of Flexible Cords

Do not use flexible wiring where frequent inspection would be difficult or where damage would be likely to occur. Flexible cords must not be

- Run through holes in walls, ceilings, or floors
- Run through doorways, windows, or similar openings unless physically protected
- Hidden in walls, ceilings, floors, conduits, or other raceways

Improper Grounding

When an electrical system is not grounded properly, a hazard exists. The most common Occupational Safety and Health Administration electrical violation is improper grounding of equipment and circuitry. The metal parts of an electrical wiring system that we touch (switch plates, ceiling light fixtures, conduit, etc.) should be grounded and at 0 V. If the system is not grounded properly, these parts may become energized. Metal parts of motors, appliances, or electronics that are plugged into improperly grounded circuits may be energized. When a circuit is not grounded properly, a hazard exists because unwanted voltage cannot be safely eliminated. If there is no safe path to ground for fault currents, exposed metal parts in damaged appliances can become energized.[10]

Ground Fault Circuit Interrupters

A ground fault circuit interrupter (GFCI) is an inexpensive lifesaving device. GFCIs detect any difference in current between the two circuit wires (the

black and white wires). This difference in current could happen when electrical equipment is not working correctly, causing leakage current. If leakage current (a ground fault) is detected in a GFCI-protected circuit, the GFCI switches off the current in the circuit, protecting you from a dangerous shock. GFCIs are set at approximately 5 mA and are designed to protect workers from electrocution. GFCIs are able to detect the loss of current resulting from leakage through a person who is beginning to be shocked. If this situation occurs, the GFCI switches off the current in the circuit. GFCIs are different from circuit breakers because they detect leakage currents rather than overloads.[11]

Assured Equipment Grounding Conductor Program

An Assured Equipment Grounding Conductor Program must cover

- All cord sets
- Receptacles not part of a building or structure
- Equipment connected by plug and cord

The program requirements include

- Specific procedures adopted by the employer
- Competent person to implement the program
- Visual inspection for damage of equipment connected by cord and plug

Overloaded Circuits

Overloads in an electrical system are hazardous because they can produce heat or arcing. Wires and other components in an electrical system or circuit have a maximum amount of current they can carry safely. If too many devices are plugged into a circuit, the electrical current will heat the wires to a very high temperature. If anyone tool uses too much current, the wires will heat up. The temperature of the wires can be high enough to cause a fire. If their insulation melts, arcing may occur. Arcing can cause a fire in the area where the overload exists, even inside a wall. In order to prevent too much current in a circuit, a circuit breaker or fuse is placed in the circuit. If there is

too much current in the circuit, the breaker "trips" and opens like a switch. If an overloaded circuit is equipped with a fuse, an internal part of the fuse melts, opening the circuit. Both breakers and fuses do the same thing: open the circuit to shut off the electrical current.[12]

Safety-Related Work Practices

To protect workers from electrical shock, the following work practices should be enforced at all times:

- Use barriers and guards to prevent passage through areas of exposed energized equipment.
- Preplan work and post hazard warnings.
- Keep working spaces and walkways clear of cords.
- Use special insulated tools when working on fuses with energized terminals.
- Don't use worn or frayed cords and cables.
- Don't fasten extension cords with staples, hang from nails, or suspend by wire.

Planning

One of the first steps in preventing electrical injuries and accidents is to plan your work and to others that you are working with or around be aware of your proposed activities. Plan to avoid falls that may result from your work. When working around electrical equipment, strictly follow the lockout/tagout program. Ensure that you or others working around electricity remove all jewelry and avoid wet conditions and overhead power lines.

Training

All employees working with electric equipment should be trained in safe work practices, which include the following:

- Deenergize electric equipment prior to inspecting or repairing.
- Using cords, cables, and electrical tools that are in good repair.
- Lockout/tagout recognition and procedures.
- Use appropriate personal protective equipment.

NFPA 70E Requirements

The NFPA 70E is a consensus standard established by the National Fire Protection Association (NFPA) that prescribes electrical safety requirements by employees in a workplace. This standard provides specific measures on how to protect employees from the heat of electric arc exposures (ie. Arc Flash). The primary purpose of the standard is to prevent work-related injuries resulting from electrical work by providing a practical safe working area for employees. The standard specifically addresses worker safety for those employees whose job is to interact with electrical equipment and systems that pose potential exposures to energized electrical equipment and parts.[13]

The NFPA 70E standard provides standards and guidelines which safeguard employees from hazards associated with such activities as the installation, inspection, operation, maintenance, and demolition of electrical conductors, electric equipment and also assists in complying with OSHA 1910 Subpart S and OSHA 1926 Subpart K.

Disclaimer: The section on NFPA 70E is strictly an overview which highlights key sections and is not to be considered all-inclusive. To fully understand NFPA please read the complete standard.

Key Sections of the NFPA 70E Standard

NFPA 70E, Article 105: States the requirement for employers to provide safety-related work procedures, training, supervision, auditing and documenting.

NFPA 70E, Article 110.1A: Covers the employer requirements of implementation of an electrical safety program as part of the overall health and safety management system.

NFPA 70E, Article 110.2D3: Requires employees to be retrained in safety-related electrical work practices and procedures every 3 years.

NFPA 70E, Article 120.2: Requires employers to identify, document, and implement lockout/tagout procedures to prevent accidental releases of energy.

NFPA 70E, Article 130.5: Requires that an arc flash study must be completed to determine if arc flash hazards exist, including the overcurrent protection devices, opening times and maintenance conditions. It further requires the assessment to updated whenever major modifications or renovations take place. This assessment must also be reviewed periodically, but not to exceed 5 years.

NFPA 70E, Article 130.5 (C)(1): Allows for two different methods of selecting PPE, (1) The Incident Energy Method (Arc Flash Study), or the Arc Flash Categories PPE Methods (Published Tables).

NFPA 70E, Article 130.7.E.2: Establishes the requirement for communicating of boundaries or barricades that contain energized conductors or circuit parts. In potential arc flash areas, the boundary is based on the inverse square of the distance to the hazard.

Additional Requirements

OSHA 29 CFR 1910.333: Determined the requirement for work-related procedures to prevent electric shock be implemented when work is performed near equipment/circuits that are or may be energized.

OSHA 29 CFR 1910.335: Requires employees working in areas of potential of electrical hazards must be provided with and use electrical protective equipment appropriate for the specific body parts to be protected.

NFPA Terminology[13]

Before discussing the requirement of NFPA 70E it is necessary to understand basic terminology. The following definitions are not all-inclusive, but are key:

Arc flash suit: Arc-rated clothing and equipment that will cover the entire body, excluding the hands and feet.

Arc rating: The value assigned to materials expressed in cal/cm^2 that describes the performance to exposure during an electrical arc discharge.

Authorized personnel: Includes either the actual person in charge of the facility, or someone designated by the person in charge who performs certain duties associated with stationary storage batteries.

Bonded (*bonding*): Refers to being connected to establish electrical continuity and conductivity.

Boundary, arc flash: When an arc flash hazard exists, an approach limit at a distance from a prospective arc source with which a person could receive a second degree burn if an electrical arc flash were to occur. *(Informational Note: A second degree burn is possible by an exposure of unprotected skin to an electric arc flash above the incident energy level of 5 J/cm^2 (1.2 cal/cm^2).*

Boundary, restricted approach: An approach limit at a distance from an exposed energized electrical conductor of circuity part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit or circuit part.

Circuit breaker: A device designed to open and close a circuity by non-automatic means and to open the circuity automatically on a predetermined overcurrent without damage to itself which properly applied within its rating.

Conductor (*bare*): A conductor having no covering or electrical insulation whatsoever.

Conductor (*covered*): A conductor encased within material of composition or thickness that is not recognized by the NFPA 70E code as electrical insulation.

Conductor, insulated: A conductor encased within material of composition or thickness that is recognized by the NFPA 70E code.

Single-line diagram: Commonly referred to as "Single Lines", is a diagram that illustrates through single lines or graphic symbols, the course of an electrical circuit or system, including the devices or parts used in the circuit or system.

Qualified person: Anyone that has demonstrated the skills and knowledge regarding the construction and operation of electrical equipment and installations and who has received the safety training on the identification of hazards to reduce the associated risks.

Working distance: A distance measured between a person's face/chest and the prospective arc source.

Working on: Intentional contact with energized electrical conductors or circuit parts with hands, feet or other body parts, tools, probes or test equipment, disregarding personal protective equipment.

General Requirements for Electrical Safety-Related Work Practices

In Section 110.2A, the employer is required to establish, document and implement an electrical work policy that requires that identified hazards be eliminated as a priority when implementing safety-related work practices. These practices must also be implemented when workers may potentially be exposed to energized electrical conductors greater than 50 volts and it is anticipated that they work within the limited approach boundary and interacts with equipment where electrical conductors or circuit parts may not be exposed, but there is a likelihood of injury from potential arc flashes.

Electrical Safety Program

The NFPA 70E Standard (Section 110.3) requires that the employer establish and maintain an electrical safety program that identifies activities that are appropriate to the risk associated to the hazards. Newly installed or modified equipment must be inspected to ensure that they meet or exceed established codes and standards before they are placed into service. In addition, the program must include a periodic maintenance of the equipment to ensure it is in proper working condition.

Electrical Safety Training

With any standard, and especially one with the potential hazards as electricity, training will always be a requirement. NFPA Section 110.4 requires those employees that have potential exposure to an electrical hazard be trained. Training shall be conducted for Qualified Persons and for Unqualified Persons.

Qualified Person training shall include precautionary techniques, electrical policies and procedures, PPE, insulating materials, shielding materials and insulated tools and test equipment. Training shall be for certain equipment and tasks to be performed. Qualified persons working within the limited approach boundary shall, at a minimum be trained in:

- Skills and techniques to determine the difference in exposed energized electrical conductors and circuit part from other parts of electrical equipment.
- Skills and techniques required to determine nominal voltage of energized electrical conductors and circuit part.
- Approach distances identified in Tables 130.4(E)(a) and Table 130.4(E)(b) of the standard regarding various voltage.
- Decision making process to do the following:

1. Perform safety planning
2. Identify electrical hazards
3. Assessing risks
4. Selecting appropriate risk control methods

Unqualified persons shall be trained in the familiarization of electrical safety-related practices necessary for their safety.

Additional training and retraining must be conducted whenever the work practices are modified and at intervals not to exceed 3 years. This training shall be conducted whenever one of the following conditions exist:

- Supervision or annual inspections identify an employee is not complying with established procedures and protocols.
- Whenever new technology or equipment is introduced.
- Whenever an employee does not perform a task more than once per year.
- Whenever the employee's duties change.

Electrical Training Documentation

Documentation shall be in accordance with the following:

- Documented whenever the employee demonstrates proficiency in the work practices being trained on.
- ***Documentation shall be retained for the duration of the employee's employment.***
- Contain the content of the training, each employee's name and dates of training.

Lockout/Tagout Procedure Training

Employees shall be trained in lockout/tagout procedures and their responsibility in executing the procedures. This training is required whenever the procedures are revised, at intervals not to exceed 3 years, or when supervision of annual inspections indicate a discrepancy in employees following the procedures.

Emergency Response Training

Employees with the potential to be exposed to electrical shock and those responsible for the safe release of affected employees will be trained in the methods of safe release, which shall occur on an annual basis. These employees will also be trained in First Aid, Emergency Response and Resuscitation, including CPR. This training shall occur at a frequency that satisfies the requirements of the certifying body, such as American Heart Association, and Red Cross, which are normally good for a period of 2 years.

Finally, all training is required to be verified annually.

Host and Contract Employer's Responsibilities

The standard requires host employers to inform contract employees of known hazards and information about the employer's installation that the contract employee needs to assess the hazards. The contract employer that their employees have been instructed on any known hazards and that they have been trained in accordance with the standard.

Test Instruments and Equipment

Testing is to be conducted only by qualified persons and includes testing, troubleshooting and voltage measuring on electrical equipment where an electrical hazard exists. Testing equipment and instruments should be rated for the circuits and equipment where they are utilized, approved for the purpose and used in accordance with manufacturer's instructions.

Lockout/Tagout Program

NFPA 70E (Section 120.2) requires employees to establish a lockout/tagout program, along with the documentation. Furthermore, the standard requires employers to implement written programs and procedures that are designed to protect workers from exposure to electrical hazards. The lockout/tagout program must be applicable to the experience and training of the workers, as well as the conditions in the workplace and applies to fixed, permanently or temporarily installed equipment and portable equipment.

Arc Flash Risk Assessment

NFPA (Section 130.5) requires employers to conduct an overall arc flash risk assessment to identify potential arc flash hazards. In addition, the risk assessment should estimate the likelihood of occurrence of injury or damage to health, as well as the severity of potential injuries or damages. Another purpose of the risk assessment is to determine the protective measures that are required, including specific use of PPE for each potential hazard. Figure 16.4 provides information on the equipment and the appropriate PPE that will be required for this specific piece of equipment.

There are five categories of personal protective equipment that range from 0 to 4. Table 16.2 provides information on each category.

Figure 16.5 is a graphic illustration of arc flash boundary areas (Yates, W. David 2024).



FIGURE 16.4
Are flash warning label.[14]

TABLE 16.2

Electrical Personal Protective Equipment

Electrical Personal Protective Equipment	
Hazard/Risk Category	**Description**
0	Untreated natural fiber shirt (long sleeve) Pants (Long) Safety glasses Hearing protection Heavy duty leather gloves (as needed)
1 4 cal/cm^2	Arc-rated long sleeve shirt Arc-rated pants or coveralls Arc-rated face shield with hard hat Safety glasses Hearing protection Leather and voltage rated gloves (as needed) Leather work shoes
2 8 cal/cm^2	Arc-rated long sleeve shirt Arc-rated pants or coveralls Arc-rated face shield and balaclava Arc flash suit hood with hard hat Safety glasses, hearing protection Leather and voltage-rated gloves (as needed) Leather work shoes
3 25 cal/cm^2	Arc-rated long sleeve jacket Arc-rated pants Arc-rated flash hood with hard hat Safety glasses, hearing protection Leather and voltage-rated gloves (as needed) Leather work shoes
4 40 cal/cm^2	Arc-rated long sleeve jacket Arc-rated pants Arc-rated flash hood with hard hat Safety glasses, hearing protection Leather and voltage rated gloves (as needed) Leather work shoes

As seen in Figure 16.5 there are three boundary levels, which include:

- Arc flash boundary
- Limited approach boundary
- Restricted approach boundary

An *arc flash boundary area* is based on the potential arc flash hazard and is calculated based on 1.2 cal/cm^2 of incident energy. This is the distance that an exposed worker not wearing personal protective equipment would receive second degree burns. It must be stated again that no worker should pass an arc flash boundary without having the required training and wearing the appropriate personal protective equipment.

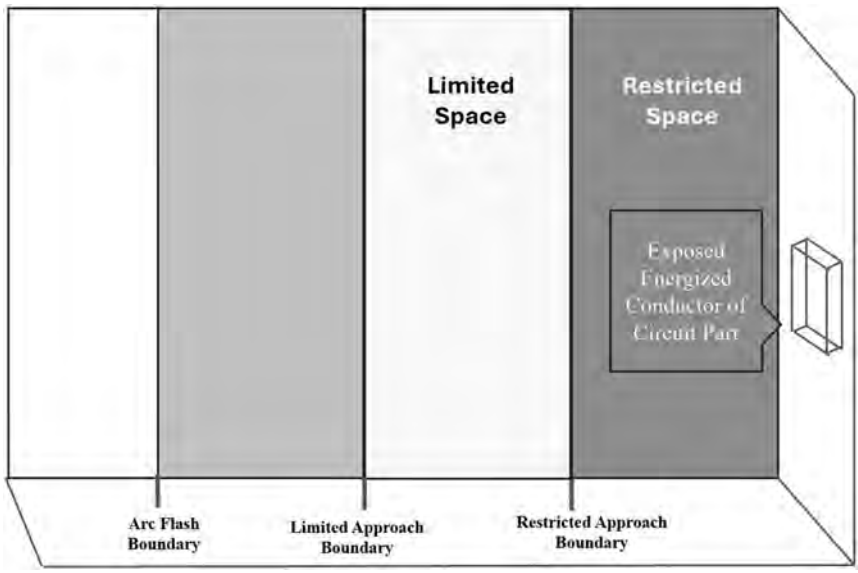


FIGURE 16.5
Arc flash boundaries (Source: Yates, W. David 2024).

As the worker moves toward the energized and exposed equipment, they will enter the *limited approach boundary*, where the potential for electric shock is present. The appropriate personal protective equipment should be worn by qualified workers.

The restricted approach boundary is the area closest to the live, exposed equipment within the restricted boundary. To pass this boundary, the worker must be a qualified worker with the proper training and personal protective equipment. In addition, to enter this area requires a written permit for the authorized person.

Key Points to Remember on Electrical Safety

1. Electrical currents move from high voltage to low voltage.
2. Voltage is measured in volts (V).
3. Current is the flow of electric charge and is measured in amperes (A).
4. Resistance is a measure of the opposition to the flow of steady electrical current and is measured in ohms (Ω).

5. Components connected in series are connected along a single path; thus, the same current flows through all of the components.
6. In a parallel circuit, the electrical current to each element in the circuit is separate.
7. Resistors are elements of electrical and electronic systems that are designed to intentionally resist the flow of electrical current through the system at a known measurement.
8. Capacitors or condensers are passive electronic components consisting of a pair of conductors separated by dielectric insulators, creating an electrical field that stores energy and produces a mechanical force between the conductors.
9. Inductors are passive electrical components that can store energy in a magnetic field created by the electric current passing through it.
10. The most common shock-related, nonfatal injury from electricity is burns.
11. Arc blasts occur when powerful, high-amperage currents arc through the air.
12. Electricity is one of the most common causes of fires and thermal burns in homes and workplaces.
13. ***Qualified person*** training shall include precautionary techniques, electrical policies and procedures, PPE, insulating materials, shielding materials and insulated tools, and test equipment. Training shall be for certain equipment and tasks to be performed.
14. In Section 110.2A, the employer is required to establish, document, and implement an electrical work policy that requires that identified hazards be eliminated as a priority when implementing safety-related work practices.
15. NFPA (Section 130.5) requires employers to conduct an overall arc flash risk assessment to identify potential arc flash hazards. In addition, the risk assessment should estimate the likelihood of occurrence of injury or damage to health, as well as the severity of potential injuries or damages.

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17

Mechanics

In this chapter, we will discuss and review the equations listed on the Board of Certified Safety Professionals (BCSP) examination reference sheet[1] related to Mechanics. Our primary focus will be on the equations related to energy, work, force, and velocity. *Mechanics* can be defined as the study of the relationships between motion, forces, and energy. As a safety professional, you must have a thorough working knowledge of this science in order to adequately perform the basic responsibilities of your position.

Energy

We will discuss two types of energy in this chapter, *potential energy* and *kinetic energy*. The laws of energy are as follows:

- The first law of thermodynamics says that energy under normal conditions cannot be created or destroyed, simply transformed from one type of energy to another (also known as the *law of conservation*).
- The second law of thermodynamics is a bit more complex than the first law, but basically states that any time you do work, including any time you make an energy transformation, some of the starting energy is going to be lost as heat.

Kinetic Energy

Kinetic energy is the energy of motion. An object that has motion, whether it be vertical or horizontal motion, has kinetic energy. There are many forms of kinetic energy, which include vibrational, rotational, and translational (energy due to motion from one location to another). The basic equation to determine kinetic energy is written as

$$\text{K.E.} = \frac{mv^2}{2}$$

or written another way:

$$\text{K.E.} = \frac{1}{2}mv^2$$

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Note: An important conversion to remember is that 1 Newton (N-m) = 1 kg (m/s²) and 1 N-m = 1 Joule/m

Example

Determine the kinetic energy of a 625-kg roller coaster car that is moving with a speed of 18.3

where
K.E. = kinetic energy (N)
m = mass of the object
v = speed of the object (velocity) m/s

$$\text{K.E.} = \frac{625\text{kg}(18.3\text{m/s})^2}{2}$$

$$\text{K.E.} = \frac{625\text{kg}\left(334.89\text{m/s}^2\right)}{2}$$

$$\text{K.E.} = \frac{209,306.25}{2}$$

$$\text{K.E.} = 104,653.13\text{kg}(\text{m/s}^2)$$

or

$$1.05 \times 10^5 \text{N}$$

Note: Kinetic energy is measured in joules. The conversion factor for joules is

$$1\,\text{joule} = 1\text{kg} \cdot \text{m/s}^2$$

Therefore, in this example, there is 1.05×10^5 J (or joules) of kinetic energy.

Potential Energy

Potential energy is the same as stored energy. Potential energy exists whenever an object that has mass has a position within a force field. The most everyday example of this is the position of objects in the earth's gravitational field. Another good example of potential energy is a round object balanced atop a pyramid. The round object is not in motion but has the potential to be in motion. The equation to determine potential energy is listed as

$$\text{P.E.} = mgh$$

where
P.E. = potential energy (J)
m = mass of the object (kg)
g = gravitational acceleration of the earth (9.8 m/s^2)
h = height above earth's surface (m)

Example

In the example of the round object balanced on the pyramid, imagine that the object weighs 2.5 kg and is balanced at a height of 6 m above the earth's surface. What is the potential energy of the object?

$$\text{P.E.} = (2.5\text{kg})(9.8\text{m/s}^2)(6\text{m})$$

$$\text{P.E.} = 147\text{J}$$

Note: It must be mentioned that in both of the previous equations, there is the assumption that no surface friction exists.

Elastic Potential Energy

Another type of potential energy important to a safety professional is *elastic potential energy.* Elastic potential energy is the energy stored in elastic materials as the result of their stretching or compressing. Elastic potential energy can be stored in rubber bands, bungee cords, trampolines, springs, an arrow drawn into a bow, and so on. The amount of elastic potential energy stored in such a device is related to the amount of stretch of the device. The more stretch of the material, the more energy that is stored. It is important to introduce the reader to *Hooke's law,* which states that if a spring is not stretched or compressed, then there is no elastic potential energy stored in it. The spring is said to be at its *equilibrium position.* The equilibrium position is the position that the spring naturally assumes when there is no force applied to it. In terms of potential energy, the equilibrium position could be called the zero-potential energy position. There is a special equation for springs, which relates the amount of elastic potential energy to the amount of stretch (or compression) and the spring constant. According to Hooke's law, the force required to stretch the spring will be directly proportional to the amount of stretch. This equation is written as follows:

$$\text{P.E.}_{\text{elastic}} = \frac{kx^2}{2}$$

where
$\text{P.E}_{\text{elastic}}$. = potential energy (elastic) (J)
k = spring constant (N/m^2)
x = amount of compression (distance in meters)

Example

A force of 100 N/m^2 is required to compress an automobile suspension spring 0.45 m. Determine the potential energy of the spring.

$$P.E._{elastic} = \frac{\left(100N / m^2\right)\left(0.45^2 m\right)}{2}$$

$$P.E._{elastic} = \frac{\left(100\ N / m^2\right)\left(0.2025m\right)}{2}$$

$$P.E._{elastic} = 10.13J$$

Note: Remember 1 N = 1 J.

Force

Force is a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects. Force is a quantity that is measured using the SI unit known as the newton. A *newton* is abbreviated as "N." To say "10 N" means 10.0 Newtons of force would be accurate. One newton is the amount of force required to give a 1-kg mass an acceleration of 1 m/s^2.

There are two types of forces: contact forces and action-at-a-distance forces.

Contact Forces

Contact forces include the following:

- *Frictional force* is a force that resists the relative motion of objects that are in contact with each other.
- *Tension force* is the force required to pull an object (opposite of compression).
- *Normal force* is the force on an object caused by the normal interaction between two objects.
- *Air resistance force* is the force between an object traveling through air and the contact with the air. As with all forces, air resistance force opposes the motion of the object.

- *Applied force* is the force applied to an object by a person or another object.
- *Spring force* is the force exerted by a compressed or stretched spring.

Action-at-a-Distance Forces

Action-at-a-distance forces is the idea that an object can be moved, changed or affected in some way as to alter it movement without ever making physical contact with the object. Action-at-a-distance forces include the following:

- *Gravitation force* is the force caused by the earth's gravitational pull.
- *Electrical force* is the force caused by an electrical field.
- *Magnetic force* is the force caused by a magnetic field.

Defining Mass and Weight

Before discussing force equations, it is necessary to clearly define the difference between mass and weight. The force of gravity acting upon an object is sometimes referred to as the weight of the object. The weight of an object (*measured in newtons*) will vary according to where in the universe the object is. The mass of an object refers to the amount of matter that is contained by the object (*measured in kilograms*) and will be the same no matter where in the universe the object is located. Weight, being equivalent to the force of gravity, is dependent upon the value of g. On the earth's surface, g is 9.8 m/s^2 (often approximated as 10 m/s^2). The weight of an object can be determined using the following equation:

$$W = mg$$

where
W = amount of work done on or to an object due to gravity
m = mass (kg)
g = gravity (9.8 m/s^2) (constant)

Example

Determine the amount of work done on or to an object having a mass of 2 kg?

$$W = 2\text{kg} \times 9.8\text{m} / \text{s}^2$$

$$W = 19.6\text{N}$$

Amount of Force

The amount of force is calculated using the following equation:

$$F = ma$$

where
F = amount of force
m = mass (kg)
a = acceleration (m/s^2)

Example

Determine the amount of force of a 2500-lb automobile with an acceleration rate of 20 m/s^2.

Note: Remember that our unit of mass is measured in kilograms for this equation. Convert pounds to kilograms.

$$\text{kg} = 2500\text{lb} \times \frac{\text{kg}}{2.2}\text{lb}$$

$$\text{kg} = 1136.4$$

Now, insert the data into the equation, as follows:

$$F = 1136.4\text{kg} \times 20\text{m} / \text{s}^2$$

$$F = 22,272.3\text{N}$$

Frictional Force

All objects on earth have some type of frictional force. The equation for determining the frictional force is as follows:

$$F = \mu N$$

where
F = frictional force (parallel to the surface) (can also be written as F_{fric}) (N)
μ = coefficient of friction
N = force acting on the surface in a direction that is normal (perpendicular) to the surface (N)



FIGURE 17.1
Frictional force example illustration (Source: Yates, W. David 2024).

Example

Determine the frictional force that results from an object having a coefficient of friction of 0.3 and 200 N (see Figure 17.1).

$$F_{fric} = 0.3(200\text{N})$$

$$F_{fric} = 60\,\text{N}$$

Force and Distance

When a force acts upon an object, there is usually some movement (displacement) of the object. The relationship between force and distance is that they have a direct proportion relationship. To calculate the effects of force on distance, we can use the following equation:

$$F_1 D_1 = F_2 D_2$$

where
F = force (N)
D = distance

Example

A simple beam is balanced on a fulcrum at the center of the beam. If a 100-kg man walks a distance of 2.3 m from the center and causes the beam to move upward 0.5 m at the opposite end, how far will a 25-kg child have to walk in order to cause the beam to move upward at the opposite end a distance of 0.5 m? Refer to Figure 17.2.

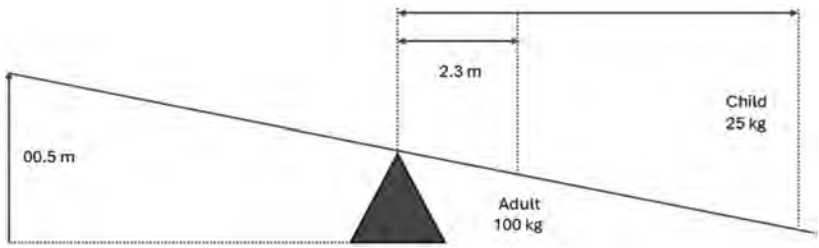


FIGURE 17.2
Example force and distance (Source: Yates, W. David 2024).

First, convert the weight of the man and child into newtons, by using the following equation:

Man:

$$\mathrm{N} = 100\mathrm{kg} \times 9.8\mathrm{m} / \mathrm{s}^2$$

$$\mathrm{N} = 980$$

Child:

$$\mathrm{N} = 25\mathrm{kg} \times 9.8\mathrm{m} / \mathrm{s}^2$$

$$\mathrm{N} = 245$$

The force of the 100-kg man and assuming a gravitational force of 9.8 m/s^2 would be 980 N. For the child, it would be 245 N. Therefore, we can now insert the data into our equation, as follows:

$$980\,\mathrm{N}\left(2.3\mathrm{m}\right) = 245\,\mathrm{N}\left(\mathrm{D}_2\right)$$

$$\frac{980\,\mathrm{N}\left(2.3\mathrm{m}\right)}{245\,\mathrm{N}} = \frac{245\,\mathrm{N}\left(D_2\right)}{245\,\mathrm{N}}$$

$$9.2\mathrm{m} = D_2$$

The 25-kg child would have to walk 9.2 m away from the center point of the beam to move the beam upward at the opposite end 0.5 m.

Momentum

Momentum is a measure of the motion of a body equal to the product of its mass and velocity. We calculate momentum by using the following equation:

$$\rho = mv$$

where
ρ = momentum (kg-m/s)
m = mass (kg)
v = velocity (m/s)

Example

An object of mass 76 kg rolls down a hill at 8.2 m/s. Calculate the momentum (which is downhill).

$$\rho = 76\,\text{kg}\left(\frac{8.2\,\text{m}}{\text{s}}\right)$$

$$\rho = 623\,\text{kg m / s}$$

Work

When a force acts upon an object to cause a displacement of the object, it is said that *work* is done upon the object. There are three key ingredients to work—force, displacement, and cause. In order for a force to qualify as having done work on an object, there must be a displacement and the force must cause the displacement. Force and displacement are vectors. When a force (F) acting on an object causes displacement (s) in a direction different from the one along where the force acts, the work done is calculated:

$$W = Fs$$

where
W = work done on or to a system (usually in joules or newtons) (1 J = 1 N × 1 m)
F = magnitude of the force (N)
s = displacement (m)

Note: This equation is for a horizontal object with no angle.

Example

A box is sitting on the floor. A force of 250 N is applied horizontally to the side of the box and the box is moved horizontally 9 m. What is the amount of work done?

$$W = (250\,\text{N})(9\,\text{m})$$

$$W = 2250\,J$$

Modified Work

As mentioned previously, the equation $W = Fs$ was written for a horizontal object with no angle, but what if you had to determine the amount of work done on an object at an angle? In order to determine the amount of work done on an object by a force applied at an angle, we use the following equation, which is NOT listed on the BCSP examination reference sheet:

$$W = Fs \times \cos\theta$$

where

W = amount of work done on or to an object (in joules or newtons) (1 J = 1 N × 1 m)

F = magnitude of force (N)

s = displacement (m)

θ = angle between the directions of force and displacement

Example

A force is acting at 30° with the horizontal on an object that is displaced 3 m along the horizontal direction. (See Figure 17.3) The normal force on the surface is 400 N and the coefficient of friction is 0.35. Calculate the work done by the force.

Step 1: Determine the amount of force based on the friction coefficient of 0.35.

$$F_{\text{fric}} = 400\,\text{N}(0.35)$$

$$F_{\text{fric}} = 140\,\text{N}$$

Step 2: Insert the data into the modified work equation, as follows:

$$W_{\text{modified}} = (140\,\text{N})(3\,\text{m})(\cos 30°)$$

$$W_{\text{modified}} = 420\,\text{N/m}(0.8660)$$

$$W_{\text{modified}} = 363.7\,\text{N}$$

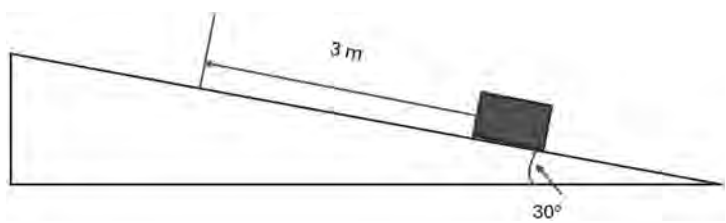


FIGURE 17.3
Modified work example diagram (Source: Yates, W. David 2024).

Newton's Laws of Motion

Newton's first law of motion states: "A body continues to maintain its state of rest or of uniform motion unless acted upon by an external unbalanced force." The second law of motion ($f = ma$) states that the net force on an object is equal to the mass of the object multiplied by its acceleration. The third law of motion states, "To every action there is an equal and opposite reaction."

Speed

Speed is a quantity of scale that determines how fast an object is moving. A fast-moving object has a high speed, while a slow-moving object has a low speed. An object with zero speed is not moving.

Velocity

Velocity is defined as the rate at which an object changes its position and is a vector quantity. In other words, velocity must have a direction. It can be written mathematically as follows:

$$v = v_o + at$$

where
v = velocity
v_o = original velocity at the start of the acceleration
a = acceleration
t = time (s)

Example

A locomotive is traveling at 5 m/s and then accelerates to 10 m/s for 30 s. How fast is the dragster traveling?

$$v = 1\frac{\text{m}}{\text{s}} + \left(3\frac{\text{m}}{\text{s}}\right)(4\text{s})$$

$$v = 1\frac{\text{m}}{\text{s}} + (12\text{m})$$

$$v = 13\text{m} / \text{s}$$

The velocity of the dragster is 45 m/s. Now, convert this velocity to miles per hour. We do this as follows:

Step 1: Convert meters per second to feet per second.

$$\frac{13\,\text{m}}{\text{s}} \times \frac{3.281\,\text{ft}}{\text{m}} = \frac{42.7\,\text{ft}}{\text{s}}$$

Step 2: Now, convert feet per second to feet per mile.

$$\frac{42.7\,\text{ft}}{\text{s}} \times \frac{3600\text{s}}{\text{h}} \times \frac{\text{mi}}{5280\text{ft}} = \frac{29.1\text{mi}}{\text{h}}$$

The locomotive traveling at 13 m/s is equivalent to traveling at 29.1 mph.

Calculating Final Velocity

The equation for calculating terminal velocity is written as

$$v^2 = v_o^2 + 2as$$

where
v = final velocity
v_o = initial velocity
a = acceleration of the object (m/s)
s = displacement of the object (change in position—normally described in distance from original position)

Example

An over-the-road truck driver working for your company is traveling at 42 m/s when he notices that the traffic light is red. The truck driver reduces his speed at a rate of –9 m/s^2. He continues this deceleration for 82 m before the light changes to green and begins to accelerate. At the point of acceleration, what is the velocity? We can calculate this velocity by inserting the known variables, as follows:

$$v^2 = (42\text{m} / \text{s})^2 + 2\left(\frac{-9\text{m}}{\text{s}^2}\right)(82\text{m})$$

$$v^2 = \left(\frac{1764\,\text{m}}{\text{s}^2}\right) + 2(-738\,\text{m})$$

$$v^2 = \frac{1764\,\text{m}}{\text{s}^2} + (-1476\,\text{m})$$

$$v^2 = 288\text{m} / \text{s}^2$$

$$\sqrt{v^2} = \sqrt{288\text{m} / \text{s}}$$

$$v = 16.97\text{m} / \text{s}$$

The velocity of the truck at Point B is 16.97 m/s. Now, convert this velocity to miles per hour. We do this as follows:

Step 1: Convert meters per second to feet per second.

$$\frac{16.97\text{m}}{\text{s}} \times \frac{3.281\text{ft}}{\text{m}} = \frac{55.68\text{ft}}{\text{s}}$$

Step 2: Now, convert feet per second to feet per mile.

$$\frac{55.68\text{ft}}{\text{s}} \times \frac{3600\text{s}}{\text{h}} \times \frac{\text{mi}}{5280\text{ft}} = \frac{37.96\text{mi}}{\text{h}}$$

The locomotive traveling at 16.97 m/s is equivalent to traveling at 38 mph.

Calculating Displacement

Displacement has been identified as change in position of an object. We calculate displacement by utilizing the following equation:

$$s = v_o t + \frac{at^2}{2}$$

where

s = displacement of the object (change in position—normally described in distance from its original position)
v_o = initial velocity
t = time
a = acceleration

Example

Using the same scenario from the "Calculating Velocity" section, where your truck driver is approaching the traffic light at a velocity of 42 m/s, when he notices the traffic light turn yellow. He immediately applies the

brakes at a velocity of –9.0 m/s and comes to a complete stop after 3 s. What is the distance traveled (displacement) from the time he applied the brakes until he comes to a complete stop? Insert the data into the equation as follows:

$$s = \frac{42\,\text{m}}{s}(3s) + \frac{\left(-9.0\frac{\text{m}}{s}\right)(3s)^2}{2}$$

$$s = 126\,\text{m} + (-40.5\,\text{m})$$

$$s = 85.5\,\text{m}$$

The distance traveled or displacement of the truck was 85.5 m.

Key Information to Remember on Mechanics

1. The first law of thermodynamics states that energy under normal conditions cannot be created or destroyed (also known as the *law of conservation*).
2. The second law of thermodynamics states that any time work is done, some of the starting energy will be lost as heat.
3. Kinetic energy is the energy of motion.
4. Kinetic energy is measured in newtons.
5. 1 N = 1 kg m/s^2.
6. Potential energy is the same as stored energy.
7. Force is a push or pull upon an object resulting from the object's interaction with another object.
8. Mass is always constant, regardless of its location in the universe. Weight is variable depending on the gravitational force.
9. Earth's gravity = 9.8 m/s^2.
10. Three key ingredients to work are force, displacement, and cause.
11. Newton's first law of motion states: "A body continues to maintain its state of rest unless acted upon by an external, unbalanced force."
12. Newton's second law of motion states: "The net force on an object is equal to the mass of the object multiplied by its acceleration."
13. Newton's third law of motion states: "To every action there is an equal and opposite reaction."

14. Speed is a scalar quantity that determines how fast an object is moving.
15. Velocity is a vector quantity that describes the rate at which an object changes its position.
16. Displacement has been identified as change in position of an object.

Reference

1. Board of Certified Safety Professionals, *Comprehensive Examination Equation Reference Sheet.* Previously retrieved from: http://www.bcsp.org/pdf/ASPCSP/ExamRef5.pdf. This link is no longer available but is embedded in the exam software.

18

Hydrostatics and Hydraulics

In preparing for the Associate Safety Professional/Certified Safety Professional examinations, the candidate must have a fundamental understanding of hydraulics and hydrostatics. In the everyday "safety world," you may not automatically understand the importance of having this understanding. However, if you just take a look around, you will see that having this knowledge can make a difference in the safety and health of employees. A question you may be asking yourself is "What is hydrostatics and hydraulics?" Hydrostatics, also known as fluid statics, is the science of fluids at rest and is a subfield within fluid mechanics. It embraces the study of the conditions under which fluids are at rest in stable equilibrium. Hydrostatics is about the pressures exerted by a fluid at rest. Any fluid is meant, not just water.[1] The use of fluid to do work is called hydraulics, and the science of fluids in motion is fluid dynamics. Hydraulics is a topic in applied science and engineering dealing with the mechanical properties of liquids. Hydraulics is used for the generation, control, and transmission of power by the use of pressurized liquids.

The study of hydrostatics and hydraulics goes back many centuries to early civilization. Early engineers and scientists succeeded in making water flow from one location to another. The problems they encountered usually involved hydraulics in the pipe flow. Whenever velocity, flow direction, or elevation changes in liquids, forces and pressures are produced.

Water Properties

Water, or wastewater, weighs 8.34 lb/gal. There are 7.48 gal/ft^3; therefore, 1 ft^3 of water will weigh 62.4 lb (8.34 lb/gal × 7.48 gal/ft^3 = 62.4 lb/ft^3). When using metric units, the weight of water is 9.8 kN/m^3. Another important property of water related to the study of hydraulics is the pressure exerted on a column of water. One foot of water height is approximately equal to 0.434 pounds per square inch (psi). This measurement will hold true, no matter what the diameter of the container (column) is.

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Hydrostatic Pressure

As mentioned previously, liquids will exert pressure and force against the walls of the container, regardless of whether they are stored in a tank or flowing through pipes. Pressure is defined as force per unit area. Pressure exerted by water is known as hydrostatic pressure. The unit of measurement in the US system is usually pounds per square inch. In the metric system, pressure is usually denoted by newtons per square meter. To convert from the US unit to the metric unit, use the conversion of 0.000145 psi = 1 N/m^2. Newtons per square meter can also be termed pascals (1 N/m^2 = 1 Pa). To calculate pressure, use the following equation:

$$P = \frac{F}{a}$$

where
P = pressure (psi)
F = force or weight (water: 62.4 lb/ft^3)
a = area (in^2)

Example

A piping system repair must be made. The pipe is 40 ft long, with a diameter of 3 ft and is installed vertically. It is filled with liquid (water), which is leaking at a point located 25 ft from the top. For operational reasons, the liquid cannot be drained before making the repairs. Before the repairs can be made, a suitable method and material decision should be made. The leaking pipe can be temporarily repaired until a scheduled shutdown can repair the leak permanently. Such a repair can be done by installing a pipe repair clamp. What is the pressure exerted at the location of the pipe repair?

Solution

To solve this problem, you must determine the force at the repair location. We know that the repair location is 25 ft from the top and the diameter of the pipe is 3 ft. Therefore, we must obtain a volume (ft^3). To do this, we use the following equation:

$$V_{\text{cylinder}} = \pi r^2 \times h$$

where
r = radius of cylinder
h = height of cylinder

In this case, the height is 25 ft and the radius of the pipe is 1.5 ft or 18 in.

$$V_{\text{cylinder}} = (31.4)(1.5)^2 \times 25\text{ft}$$

$$V_{\text{cylinder}} = (3.14)\left(2.25\text{ft}^2\right)(25\text{ft})$$

$$V_{\text{cylinder}} = 177\,\text{ft}$$

There is 177 ft^3 of water at this location of the pipe and water weighs 62.4 lb/ft^3; therefore, the weight of the water at the point of repairs is 11,063 lb. Now, we must calculate the area for the pipe, which is determined by

$$\text{Area}_{\text{pipe}} = \pi r^2$$

$$\text{Area}_{\text{pipe}} = (3.14)(18\text{in.})^2$$

$$\text{Area}_{\text{pipe}} = (3.14)\left(324\text{in.}^2\right)$$

$$\text{Area}_{\text{pipe}} = 1018\,\text{in.}^2$$

We can now solve for the pressure, using the following equation:

$$P = \frac{F}{a}$$

$$P = \frac{11{,}063\text{lb}}{1018\text{in.}^2}$$

$$P = 10.87\text{lb / in.}^2$$

The pressure at the point of repairs is 10.87 psi.

Torricelli's Law

Torricelli's law, also known as *Torricelli's theorem*,[2] is a theorem in fluid dynamics relating the speed of fluid flowing out of an opening to the height of fluid above the opening. Torricelli's law states that the velocity, (v), of a fluid through a sharp-edged hole at the bottom of a tank filled to a depth h is the same as the speed that a body (in this case, a drop of water) would acquire in falling freely from a height (head, in feet) h, that is, where g is the acceleration due to gravity.

Torricelli's theorem, also called *Torricelli's law*, *Torricelli's principle*, or *Torricelli's equation*, states that the speed, v, of a liquid flowing under the force of gravity out of an opening in a tank is proportional jointly to the square root of the vertical distance, h, between the liquid surface and the center of the opening and to the square root of twice the acceleration caused by gravity, $2g$, or simply $v = (2gh)^{1/2}$. (The value of the acceleration caused by gravity at the earth's

surface is approximately 32.2 ft/s^2, or 9.8 m/s^2.) The theorem is named after Evangelista Torricelli, who discovered it in 1643.

The speed of the portion of water flowing through an opening in a tank a given distance, h, below the water surface is the same as the speed that would be attained by a drop of water falling freely under the force of gravity alone (i.e., neglecting effects of air) through the same distance, h. The speed of efflux is independent of the direction of flow; at the point of the opening, the speed is given by this equation, whether the opening is directed upward, downward, or horizontally.

The equation is written as follows[2]:

$$v = \sqrt{2gh}$$

where
v = velocity (ft/s)
g = acceleration due to gravity (9.8 m/s or 32 ft/s)
h = head (ft)

Example

A valve needs to be installed on a vertical pipe. In order to select the correct valve, the velocity of the liquid, which is similar in all aspects to water must be determined. The tank at its highest point is 31 ft. Determine the velocity of the liquid at that height.

Solution

$$\mathrm{v} = \sqrt{2\mathrm{gh}}$$

$$\mathrm{v} = \sqrt{2\left(\frac{32\mathrm{ft}}{\mathrm{s}}\right)(31\mathrm{ft})}$$

$$\mathrm{v} = \sqrt{1984\ ft/s}$$

$$v = 44.5\frac{ft}{s}$$

The pressure may be calculated using the following equation:

$$P = 0.433 \times h$$

where
P = pressure (psi)
h = head (ft)

Example

What is the pressure at discharge, if the nozzle of a fire suppression system is 50 psi?

Solution

This problem requires us to solve for head (h).

$$P = 0.433 \times h$$

$$50\,\text{psi} = 0.433\ \text{psi / ft} \times h$$

$$\frac{50\,\text{psi}}{0.433} = \frac{0.433 \times h}{0.433}$$

$$115.5\text{psi} = h$$

Head Pressure

In fluid dynamics, *head* is a concept that relates the energy in an incompressible fluid to the height of an equivalent static column of that fluid. From Bernoulli's principle, the total energy at a given point in a fluid is the energy associated with the movement of the fluid, plus energy from pressure in the fluid, plus energy from the height of the fluid relative to an arbitrary datum (a reference from which measurements are made). Head is expressed in units of height such as meters or feet. The hydraulic head can be used to determine a *hydraulic gradient* between two or more points. We can calculate the head pressure using the following equation:

$$h_p = \frac{p}{w}$$

where

h_p = head pressure (ft)
p = gauge pressure
w = weight of water

Example

Given a gauge pressure of 20 psi and the weight of water at 62.4 lb/ft^3, calculate the head pressure.

Solution

To solve this equation, you must convert psi to lb/ft^2, as follows:

$$20\frac{\text{lb}}{\text{in.}^2}\times\left(12\frac{\text{in.}}{\text{ft}}\right)\times\left(12\frac{\text{in.}}{\text{ft}}\right)=2880\text{lb}/\text{ft}^2$$

We now insert the data into our original equation.

$$h_{\text{P}}=\frac{2880\text{lb}/\text{ft}^2}{62.4\text{lb}/\text{ft}^3}$$

$$h_{\text{P}}=46.2\text{ft}$$

It means that the water, under this pressure, will rise vertically 46.2 ft.

Velocity Head

Velocity head can be described as the velocity of a fluid expressed in terms of the head or static pressure required to produce that velocity. *Velocity head* is attributed to the motion of a fluid (kinetic energy). Velocity head can be calculated as follows:

$$h_{\text{v}}=\frac{v^2}{2g}$$

where

h_{v} = velocity expressed in head (ft)
v = velocity (ft/s, m/s, etc.)
g = acceleration of gravity (9.8 m/s^2 or 32.2 ft/s^2)

Example

Calculate the head velocity if water is flowing through a pipe at 5 ft/s.

$$h_{\text{v}}=\frac{(5\text{ft}/\text{s})^2}{(2)32.2\text{ft}/\text{s}^2}$$

$$h_{\text{v}}=\frac{25\text{ft}/\text{s}}{64.4\text{ft}/\text{s}^2}$$

$$h_{\text{v}}=0.39\text{ft}$$

Velocity Pressure at Constant Laminar Velocity

Laminar flow, sometimes known as streamline flow, occurs when a fluid flows in parallel layers, with no disruption between the layers. At low velocities, the fluid tends to flow without lateral mixing, and adjacent layers slide past

one another like playing cards. There are no cross currents perpendicular to the direction of flow; neither are there eddies or swirls of fluids. In laminar flow, the motion of the particles of fluid is very orderly with all particles moving in straight lines parallel to the pipe walls. In fluid dynamics, laminar flow is a flow regime characterized by high momentum diffusion and low momentum convection.

When a fluid is flowing through a closed channel such as a pipe or between two flat plates, either two types of flow may occur depending on the velocity of the fluid: laminar flow or turbulent flow. Laminar flow is the opposite of turbulent flow, which occurs at higher velocities where eddies or small packets of fluid particles form leading to lateral mixing. In nonscientific terms, laminar flow is "smooth," while turbulent flow is "rough."

The type of flow occurring in a fluid in a channel is important in fluid dynamics problems. The dimensionless Reynolds number is an important parameter in the equations that describe whether flow conditions lead to laminar or turbulent flow. In the case of flow through a straight pipe with a circular cross section, Reynolds numbers of less than 2100 are generally considered to be of a laminar type; however, the Reynolds number upon which laminar flows become turbulent is dependent upon the flow geometry. When the Reynolds number is much less than 1, creeping motion or Stokes flow occurs. This is an extreme case of laminar flow where viscous (friction) effects are much greater than inertial forces. The common application of laminar flow would be in the smooth flow of a viscous liquid through a tube or pipe. In that case, the velocity of flow varies from zero at the walls to a maximum along the centerline of the vessel. The flow profile of laminar flow in a tube can be calculated by dividing the flow into thin cylindrical elements and applying the viscous force to them.[3]

The Reynolds number classification is listed as follows:

- Laminar flow: Re < 2000
- Transitional flow: 2000 < Re < 4000
- Turbulent flow: Re > 4000

The pressure at constant laminar velocity can be calculated using the following equation:

$$p_v = \frac{Q^2}{891d^4}$$

where

p_v = pressure at constant laminar flow (psi)
Q = flow rate (gpm)
d = pipe diameter (in., ft, m)

Example

Calculate the pressure of a pipe measuring 18 in. in diameter with a flow rate of 2500 gpm.

$$p_v = \frac{(2500\,\text{gpm})^2}{(891)(18\,\text{in.})^4}$$

$$p_v = \frac{6,250,000\,\text{gpm}}{93,533,616\,\text{in.}^4}$$

$$p_v = 0.067\,\text{psi}$$

Flow Rates and Pressure Drops

A piping system, such as a fire water supply system, can operate at different flow rates (Q). If you were to operate at one pressure, increase or decrease the pressure to achieve the maximum operating flow rate, and then the flow rate would change. For example, if you were operating at Q = 350 gpm and 20 psi, the measured pressure would be under the conditions for 350 gpm. However, if you increase the flow pressure to 25 psi, then the flow rate would also change.

You can calculate this difference in pressure by using the following equation:

$$Q_2 = Q_1\left[\frac{(S - R_2)^{0.54}}{(S - R_1)^{0.54}}\right]$$

where

Q_2 = final flow rate after increasing the flow rate of system 1 (gpm)

Q_1 = flow rate under original conditions (gpm)

S = highest pressure in the system (psi)

R_1 = pressure that the system dropped to as a result of running at specific conditions (1) (psi)

R_2 = pressure that the system dropped to as a result of running at specific conditions (2) (psi)

Example

A fire system is operating at 350 gpm and at 20 psi (0.03 psi drop). If the operator were to increase the pressure to 25 psi (0.086 psi drop), what is the final flow rate?

$$Q_2 = 350\,\text{gpm}\left[\frac{(25\,\text{psi} - 0.86\,\text{psi})^{0.54}}{(25\,\text{psi} - 0.03\,\text{psi})^{0.54}}\right]$$

$$Q_2 = 350\,\text{gpm}\left[\frac{5.58\,\text{psi}}{5.68\,\text{psi}}\right]$$

$$Q_2 = 350\,\text{gpm}\left[0.98\right]$$

$$Q_2 = 343.7\,\text{gpm}$$

The amount of pressure used in a system is calculated using the following equation:

$$P = \left(\frac{Q}{K}\right)^2$$

where
P = pressure (psi)
Q = flow rate (gpm)
K = discharge coefficient (0–1)

In a nozzle or other constriction, the discharge coefficient is the ratio of the mass flow rate at the discharge end of the nozzle to that of an ideal nozzle that expands an identical working fluid from the same initial conditions to the same exit pressure. It is also known as coefficient of discharge (Sci-Tech[4]).

Example

A fire system has a wide-angle full cone nozzle with a flow rate of 5 gpm and a discharge coefficient of 0.79. What is the pressure from the nozzle?

$$P = \left(\frac{5\,\text{gpm}}{0.79}\right)^2$$

$$P = 6.33^2$$

$$P = 40.05\,\text{psi}$$

Example

A system is operating at 350 gpm at 25 psi. If the system pressure were increased to 30 psi, calculate the flow rate.

Solution

$$\frac{350\,\text{gpm}}{Q_2} = \frac{\sqrt{25\,\text{psi}}}{\sqrt{30\,\text{psi}}}$$

$$\frac{350\,\text{gpm}}{Q_2} = \frac{5\,\text{psi}}{5.48\,\text{psi}}$$

$$\frac{350\ gpm}{Q_2} = 0.91$$

$$(Q_2)\frac{350\,\text{gpm}}{Q_2} = (0.91)(Q_2)$$

$$\frac{350\,\text{gpm}}{0.91} = \frac{0.91Q_2}{0.91}$$

$$384.62\text{gpm} = Q_2$$

Flow Rates and Pressures

There is a direct relationship between flow rates and pressures in the system. This relationship is calculated using the following equation:

$$\frac{Q_1}{Q_2} = \frac{\sqrt{P_1}}{\sqrt{P_2}}$$

where
Q = flow rate (gpm)
P = pressure (psi)

Calculating Pressure Loss Due to Friction

To calculate the pressure loss due to friction, use the following equation:

$$P_d = \frac{4.52Q^{1.85}}{C^{1.85}d^{4.87}}$$

where
P_d = pressure lost to friction (psi/ft)
Q = flow rate (gpm)
C = coefficient of roughness of the pipe
d = inside pipe diameter (in.)

Example

A fire system has a piping system with 6 in. inside diameter, with a coefficient of friction of 120 and a flow rate of 800 gpm. What is the total friction loss in 500 ft of pipe?

Solution

$$P_{\mathrm{d}} = \frac{4.52(800\mathrm{gpm})^{1.85}}{(120)^{1.85}\,\mathrm{d}(6\mathrm{in.})^{4.87}}$$

$$P_{\mathrm{d}} = \frac{4.52(2{,}344{,}809.9\mathrm{gpm})}{(7022.4)(6160.2\mathrm{in.})}$$

$$P_{\mathrm{d}} = \frac{10{,}598{,}540.75\mathrm{gpm}}{43{,}256{,}924.4\mathrm{in.}}$$

$$P_{\mathrm{d}} = 0.006\mathrm{psi}/\mathrm{ft}$$

The total friction loss in 500 ft of piping is 0.006 psi/ft × 500 ft = 3 psi.

Bernoulli's Principle

In fluid dynamics, *Bernoulli's principle* states that for an inviscid flow, an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy.[1,2] Bernoulli's principle is named after the Dutch-Swiss mathematician Daniel Bernoulli who published his principle in his book *Hydrodynamica* in 1738.

Bernoulli's principle can be applied to various types of fluid flow, resulting in what is loosely denoted as *Bernoulli's equation*. In fact, there are different forms of the Bernoulli equation for different types of flow. The simple form of Bernoulli's principle is valid for incompressible flows (e.g., most liquid flows) and also for compressible flows (e.g., gases) moving at low Mach numbers. More advanced forms may in some cases be applied to compressible flows at higher Mach numbers (see the derivations of the Bernoulli equation).

Bernoulli's principle can be derived from the principle of conservation of energy. This states that, in a steady flow, the sum of all forms of mechanical energy in a fluid along a streamline is the same at all points on that streamline. This requires that the sum of kinetic energy and potential energy remain constant. If the fluid is flowing out of a reservoir, the sum of all forms of energy is the same on all streamlines because in a reservoir, the energy per unit mass (the sum of pressure and gravitational potential $\rho\, gh$) is the same everywhere.

Fluid particles are subject only to pressure and their own weight. If a fluid is flowing horizontally and along a section of a streamline, where the speed

increases, it can only be because the fluid on that section has moved from a region of higher pressure to a region of lower pressure, and if its speed decreases, it can only be because it has moved from a region of lower pressure to a region of higher pressure. Consequently, within a fluid flowing horizontally, the highest speed occurs where the pressure is lowest, and the lowest speed occurs where the pressure is highest.[5]

The form of the equation supplied on the examination is as follows:

$$\frac{v_A^2}{2_g} + \frac{p_A}{w} + z_A = \frac{v_B^2}{2_g} + \frac{p_B}{w} + z_B + h_{AB}$$

where

v_A = velocity at point A (ft/s, m/s)
v_B = velocity at point B (ft/s, ms/s)
g = gravity (9.8 m/s or 32.2 ft/s)
p_A = pressure at point A (psi)
p_B = pressure at point B (psi)
z_A = elevation at point A (ft)
z_B = elevation at point B (ft)
w = weight (not mass) ($\rho \times g$)
h_{AB} = the piezometric head (the sum of the elevation z and the pressure head between points A and B)

Example

In a horizontally installed fire system, water (density of 62 lb/ft^3) flows through a 6-in. pipe. The head loss in a 1000-ft section of the system has a head loss of 50 ft. The residual pressure at point A is 45 psi and the velocity at point A is 5 ft/s. The velocity at point B is 7 ft/s. What is the residual pressure at point B?

Solution

$$\frac{5^2\,\text{ft/s}}{2\left(32.2\frac{\text{ft}}{\text{s}^2}\right)} + \frac{45\text{psi}}{62} + 0\text{ft} = \frac{7^2\,\text{ft/s}}{2\left(32.2\frac{\text{ft}}{\text{s}^2}\right)} + \frac{p_B}{62} + 0\,\text{ft} + 50\text{ft}$$

$$\frac{25\,\text{ft/s}}{64.4\frac{\text{ft}}{\text{s}^2}} + \frac{45\,\text{psi}}{62}\left(144\frac{\text{in.}^2}{\text{ft}^2}\right) + 0\,\text{ft} = \frac{49\,\text{ft/s}}{62\frac{\text{ft}}{\text{s}^2}} + \frac{p_B}{62} + 50\,\text{ft}$$

$$0.388 + 104.52\text{psi} + 0\text{ft} = 0.766 + \frac{p_B}{62} + 50\text{ft}$$

$$104.91\frac{\text{psi}}{\text{ft}} = 50.766 + \frac{p_B}{62}$$

$$104.91 - 50.766 = 50.766 - 50.766 + \frac{p_B}{62}$$

$$54.14(62) = (62)\frac{p_B}{62}$$

$$3356.93\text{psf} = p_B$$

To get the actual psi value, you must divide by 144 in.^{2} which results in 23.3 psi.

Key Information to Remember on Hydrostatics and Hydraulics

1. Hydrostatics, also known as fluid statics, is the science of fluids at rest and is a subfield within fluid mechanics.
2. Hydraulics is the science of fluids in motion, also called fluid dynamics.
3. Water weight, 8.34 lb/gal or 62.4 lb/ft^3.
4. Pressure is defined as force per unit area.
5. Torricelli's law is a theorem in fluid dynamics relating the speed of fluid flowing out of an opening to the height of fluid above the opening.
6. In fluid dynamics, head is a concept that relates energy in an incompressible fluid to the height of an equivalent static column of that fluid.
7. Velocity head can be described as the velocity of a fluid expressed in terms of the head or static pressure required to produce that velocity.
8. Reynolds number: <2000 is laminar, 2000 < Re < 4000 is transitional, and >4000 is turbulent.
9. Bernoulli's principle states that for an inviscid flow, an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy.

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19

Training

One of the most fundamental and important roles that any safety professional will undertake is that of training. The majority of safety professionals conduct training every day, whether in a formal classroom or conducting safety inspections or audits. Nearly every aspect of the Occupational Safety and Health Administration's regulatory program requires that employees be adequately trained. It is for this reason that a chapter on training has been included. This chapter will focus primarily on the "adult learner", as the learning is far different than that of a child, youth or teenager. Chapter 19 covers topics including "Principles of Adult Learning"; "Delivery Methods"; "Training Needs-Analysis"; "Training Program Development"; and "Media Presentations".

Principles of Adult Learning

The overwhelming majority of the persons that you will be teaching are adults, and adults learn differently compared to children. Therefore, it is necessary to understand the principles of adult learning. Adult learners have special needs. There are six characteristics of adult learners. Adult learners

- Are autonomous and self-directed.
- Have a foundation of life experiences and knowledge.
- Are goal oriented.
- Are relevancy oriented.
- Are practical in nature.
- Need to be shown respect.

These characteristics have implications that the trainer must understand. For each of the characteristics, the implications are as follows:

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Adult Learners Are Autonomous and Self-Directed

Implications:

- Involve participants in the training.
- Instructors should serve as facilitators.
- Instructors must determine the interests of the students.

Adult Learners Have a Foundation of Life Experiences and Knowledge

Implications:

- Trainers must recognize the expertise of the students.
- Trainers must encourage participants to share their experiences and knowledge with other students in the training.

Adult Learners Are Goal Oriented

Implications:

- The instructor must be organized in his or her training sessions.
- The training must have clear and understandable objectives.

Adult Learners Are Relevancy Oriented

Implications:

- The instructor/trainer must explain how the training objectives relate to the training activities.

Adult Learners Are Practical

Implications:

- The instructor should demonstrate the relevance of the training to the actual job.

Adult Learners Need to Be Respected

Implications:

- The instructor should acknowledge the wealth of knowledge and experiences the participants bring to the training.
- Treat all participants in the training as equals rather than subordinates.



FIGURE 19.1
ADDIE system (Source: Yates, W. David 2024).

ADDIE System of Training

Practicing safety professionals all know that adult training is greatly different from educating children. When developing training programs for adults, one of the most common models or systems deployed is that of the ADDIE System. ADDIE, of course, is an acronym for showing the training cycle. It is based on Deming's PDCA Model of Plan-Do-Check-Act (see Figure 19.1).

As illustrated in the graph in Figure 19.1, the acronym ADDIE stands for the following[1]:

- **A—Analyze**: This phase of the model or system is probably the most critical, as it serves to form the basis of planning for the training (who must be trained, what is to be trained on, and where will the training occur).
- **D—Design**: The design step gives instructions on how to reach the final objective of good quality training. It provides an outline of the training program.
- **D—Develop**: During this phase, the creation of the program begins. Objectives of the training are developed during this phase.

- **I—Implement**: At this point, the developed program begins to be taught or facilitated.
- **E—Evaluate**: The final step or phase is the evaluation of not only the training, but also whether the objectives were met.

As mentioned previously, this model is based on Deming's PDCA model, therefore, the ADDIE Model is also a continuous improvement model.

Safety Training Program

Most companies have a safety training program. Contrary to the way many programs are put into place, the safety training program should be well thought out, and a needs analysis should be performed prior to developing a training program. The primary purpose of training is to solve an actual problem in the workplace or to modify specific behaviors. To structure a formal training program, the following steps must be implemented:

- *Performance analysis*: This first step in the process is to determine, first and foremost, if training is the right solution to the actual workplace problem. If it is determined that training is at least part of the solution, then extensive research into what specific job skills or knowledge are needed.
- *Instructional design*: Based on the needs analysis, the safety professional should develop the methods that will be used to train employees, the materials that are to be used in the training, and the order that the training events will occur.
- *Materials acquisition or development*: The instructor of the training course should acquire through purchase or develop the training materials to be used in the training. It is important in this phase to target the specific audience. "One size does not fit all." The materials should reinforce the training objectives being sought. Keep in mind the adult learning characteristics when acquiring or developing the training materials.
- *Delivery of training*: The training is delivered via the chosen method. Training delivery methods will be discussed in more depth within this chapter.
- *Course evaluation*: Once the training has been delivered, a course evaluation should be conducted. The purpose of the course evaluation is to obtain feedback from the participants to ensure that future training sessions are improved. In addition to the evaluation of the course, the actual work site should be evaluated to determine if the training is effective.

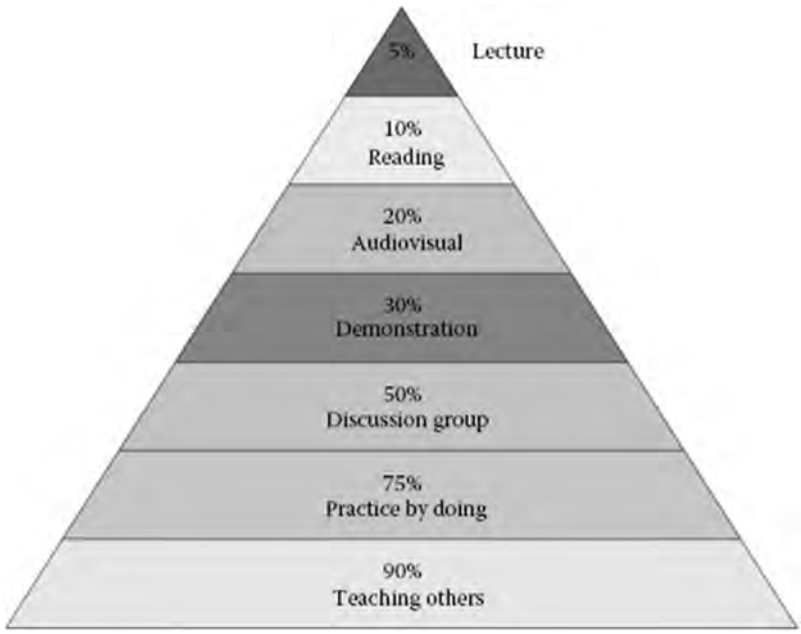


FIGURE 19.2
Retention rates based on delivery methods.[2] (Source: Yates, W. David 2019).

Delivery Methods

There are three major types of delivery methods used to deliver the training. An important aspect of delivery methods to consider when determining specific delivery methods is the retention of information. Figure 19.2 illustrates the average retention of information based on delivery methods.

The three major types of delivery methods include instructor-led training, self-paced training, and structured on-the-job training. Each of these is discussed in the following.

Instructor-Led Training

This type of delivery method has traditionally been conducted by an instructor who presents the material in a classroom. However, in today's society, the Internet has become an integral tool for almost everyone, including safety professionals. As such, one instructor can conduct training from a central location and broadcast via the Internet or through an online meeting room. The Internet variation of the instructor-led delivery method has unlimited possibilities and a variety of ways that it can be set up. In either case, an instructor serves as a facilitator and keeps the instruction flowing toward an established objective.

Self-Paced Learning

In self-paced learning, the student typically learns at their own pace by using training materials such as workbooks or textbooks. A newer version of the self-paced learning methodology is the inclusion of computer-based training (CBT) modules. In this method, the participant goes through a series of training modules on a computer or through an online service. At the end of the course, testing is completed, and a certificate can be printed out for documentation purposes. In the early stages, CBT was not a staple in the safety training program. However, with numerous improvements, CBT is now a viable option for providing safety training. When selecting a CBT, it is advisable to purchase or develop one that requires the student to complete all courses of study prior to taking the test. Some CBT modules will allow the student to go straight to the test. This type of CBT should be avoided.

Structured On-the-Job Training

This type of training delivery is usually conducted by a work supervisor who acts as a coach or guide in the training process. When conducting structured on-the-job training, a clear set of goals and objectives should be established prior to the training. The supervisor, acting as the instructor, should document that the training has been completed.

Training Needs Analysis

As discussed previously, a training needs analysis should be performed prior to developing and implementing a training program. Part of the needs analysis is to determine what the level of worker performance is and compare it to a desired performance level. Training needs can be analyzed by observing performance, interviewing employees, reviewing quality scores, and completing employee questionnaires.

Type of Needs Analysis

Needs analysis can be conducted using an assortment of methods. Some of the major types of needs analysis are listed as follows:

Context analysis: A context analysis is performed to determine the desired training needed by the organization. The major objective of this analysis is to answer why training is the recommended solution, who decided that the training would be conducted, and what is the history of the organization in regard to employee training.

User analysis: User analysis focuses on the prospective students and instructors. It determines who is going to receive or instruct the

training and what their existing knowledge level of the subject matter is. In addition, user analysis assists in determining what the most appropriate learning style of potential participants is.

Work analysis: Work analysis focuses on the desired skill and performance requirements of the job being performed. It can also be referred to as a task or job analysis. A good place to start in this type of analysis is a review of the various job descriptions and requirements.

Content analysis: A thorough analysis of the documents used in the job is conducted. Such analysis may include a review of laws or written procedures that are directly related to the task or job. An example of the type of document that may be reviewed is confined space entry requirements.

Training suitability analysis: A thorough analysis of the task, job, or project is performed to determine if training is the desired (or only) solution to performance problems. Training may not necessarily be the answer to correcting or improving employee behaviors. Training may be part of the solution. In either case, it should be recognized for what it is. This is important, especially when the evaluation phase is conducted.

Cost–benefit analysis: Cost–benefit analyses are conducted to determine the return on investment to the company from the original investment of training costs.

Techniques

As mentioned above, there are several techniques that can be used to conduct a training needs analysis. A few of them are listed below:

- Direct observation
- Questionnaires
- Consultation with employees having knowledge of the task
- Review of documents and relevant literature
- Interviews
- Focus groups
- Tests
- Records and reports (i.e., quality assurance/quality control reports)
- Representative samples of behaviors

Training Program Development

Once a needs analysis has been conducted and the decision has been made that training is the answer, or part of the answer, a training program must be developed. Training program development involves a systematic approach, which includes the following steps or phases:

- Written performance objectives
- Content outline
- Selecting the training delivery method
- Selecting the materials to be used in the training
- Testing and evaluation

Each of the steps or phases is discussed in more detail within this chapter.

Written Performance Objectives

Once the training needs have been determined, you must identify specific goals and objectives of the training program. These goals and objectives should be clearly identified and must be written. The goals and objectives should identify exactly what employees are expected to do to perform their tasks, to improve their performance, and to improve their behavior.

Objectives need to be well thought out and planned in order for the training to be successful. In addition, objectives should be clear, concise, measurable, and shared with the employees. The four elements to consider when developing the objectives are as follows:

- Target audience—Who will receive the training?
- Behavior—What observable action will the employee exhibit during evaluation?
- Condition—Under what circumstances will the desired action be performed? What materials and equipment will be used?
- Degree/standard—How well must a task be accomplished? What score must be achieved?[1]

Developing Course Outline

A course outline that clearly identifies how the course is to be conducted should be developed. The course outline will serve as the basis for the

curriculum development. The following are some of the items included in the course outline:

- General course description
- What is and isn't covered in the course
- Teaching approach (i.e., lecture, discussion, hands-on, etc.)
- Prerequisites (other courses, advanced job skills, etc.)
- Goals and objectives
- List the goals and objectives of successfully completing the course
- Outline of course structure
- How the course will be broken down (i.e., modules, hands-on, etc.)
- Time required to complete the training
- Course requirements
- Evaluation criteria

Selection of Training Delivery Method

The primary question for a training developer to ask is, "Will the chosen training method deliver the desired results?" Therefore, it is necessary to select a method of delivery that meets the desired objectives of the training program and is economical to the organization. In addition, the method of delivery must be adequate for the target audience's skill and literacy level.

Development of Course Materials

Materials used in the course of instruction should be selected with a specific purpose in mind. The learning retention of most adults, as identified in Figure 19.2, materials should be presented in a manner that is instrumental in achieving the goals and objectives of the training. Materials should include an introduction, presentation, practice, and feedback, and a summary of the materials presented. Materials may include text, graphics, charts, examples of "real-world" experiences, and a host of other items. Media presentations will be discussed later in this chapter.

Testing and Evaluation

When evaluating the success or failure of a training program, instructors often perform appraisals of their students. This section focuses on the testing and evaluation of the students in a course, not on the evaluation of the overall safety program. Testing and evaluation can be performed by using pretests, review tests, or posttests.

Pretests

Pretests are administered to determine the skill level of students prior to being presented the course materials. It is a valuable tool that can be used to assist in quantitative measurements of the course.

Review Tests

Review tests are given during the presentation phase of the training, but before the actual posttest. This type of test is beneficial whenever courses are more than a couple of hours in length. For example, an instructor of a 40-h training course may give review tests at the end of each day or training period. Review tests are beneficial tools for the instructor and the students, by letting the instructor know if students are receiving the materials and letting students know what type of evaluation is expected.

Posttests

Posttests should be designed to determine if the participant can perform the learning objectives. Often, the posttests contain the same information presented in the pretests and review tests. The final results can be quantitatively measured to determine if the course materials or delivery methods are adequate to achieve the desired goals and objectives of the training course.

Media Presentations

Some safety professionals are old enough to remember attending classes where professors made use of overhead slide transparencies. This method of presenting materials was considered "state-of-the-art" at the time. If we were to use transparencies today, most students would wonder how up-to-date the training would be. Technologies have advanced in the education field to the point that training materials and media are virtually endless. Computers serve as great tools for communicating ideas and information. As

we mentioned previously, training can be conducted via web-based training programs or online meeting rooms.

PowerPoint Presentations

One of the most common and useful tools for presenting classroom-based training is Microsoft PowerPoint software and a projector. This method of presentation can provide both visual and audible formats. In the graphic presentation using this method, font styles and sizes are important. There is a wide variety of font styles that can be used including serifs (fonts with curves or lines at the end of the letters), sans serifs (fonts without curves or lines at the end of letters), script fonts (cursive writing style), and Gothic or Helvetica (fonts without curves or lines). Font size is extremely important in visual presentations. After all, if a participant cannot see the information, then the information cannot be retained. As a general rule, fonts should be at least 16 points, with at least a 2-point size difference in the text and the headline. Block letters tend to work best in this visual presentation. Table 19.1 shows the different sizes of font for various distances.

Charts and Graphs

Charts and graphs can be inserted into PowerPoint presentations or presented separately. A chart is a visual representation of data, in which "the data are represented by symbols, such as bars in a bar chart, lines in a line chart, or slices in a pie chart." A chart can represent tabular numeric data, functions, or some kinds of qualitative structures. A graph may refer to a graphic (such as a chart or diagram) depicting the relationship between two or more variables used, for instance, in visualizing scientific data.

TABLE 19.1

Height, Thickness, and Distance of PowerPoint Fonts

Distance (ft)	Letter Height (in.)	Letter Thickness (in.)
25	1	1/8
50	1 3/4	1/4
75	3	1/3–1/2
100	3 1/2	1/2

Key Information to Remember on Training

1. Adult learners are autonomous and self-directed, have a foundation of life experiences and knowledge, are goal-oriented, are relevance-oriented, are practical in nature, and need to be shown respect.
2. Training program development includes the following steps: performance analysis, instructional design, materials acquisition or development, training delivery, and course evaluation.
3. The three basic types of delivery methods include instructor-led training, self-paced learning, and structured on-the-job training.
4. A training needs analysis is the first step in developing a training program.
5. Training program development includes written performance objectives, preparing a course outline, selecting the training delivery method, selecting the materials to be used in the training, and testing and evaluation.
6. Pretests are administered prior to the presentation of course information and are designed to provide the starting point of knowledge.
7. Review tests are useful in longer courses.
8. Posttests should be designed to determine if the participant can perform the learning objectives.
9. Font size (height and width) varies with distances from the screen.

References

1. ADDIE Model Explained, Academy to Innovate HR. Retrieved from: https://www.aihr.com/blog/addie-model/.
2. Texas Department of Insurance, Division of Workers' Compensation Workplace Safety. 2010. Available at http://www.tdi.state.tx.us/pubs/videoresource/stp-trainingprod.pdf.

20

Engineering Economics

Engineering economics is a subcategory of economics that is specifically designed for the engineering professions. The essential idea behind engineering economics is that money generates money. An amount of $10.00 today cannot be compared to $10.00 a year from now without adjusting for the investment potential.[1] Some may be curious at this point as to what economics has to do with the safety profession. Regardless of what some safety professionals may believe, safety is a business unit. Some examples of this are (a) a safety manager, requesting the company to authorize funds to purchase safety equipment to reduce the number of specific types of injuries; (b) the safety manager requesting to purchase a computer-based training program; or (c) the safety manager has eight (8) different manufacturing facilities with a central safety budget and must determine where to spend allocate the funding. Safety managers and professionals are often asked to justify expenditures in economic terms, and not just in terms of "it's the right thing to do." When equipped with viable information on the associated costs, including the "cost of money," requests are more likely to be approved. At this point, it is worth mentioning that not all safety expenditures are based entirely on financial constraints. However, financial considerations are an integral part of any decision-making process. In this chapter present and future value of money, interest, and various payment structures as they relate to safety will be the primary focus.

Simple Interest

When borrowing money, the lender will, under normal circumstances, charge interest on that money (**cost of money**). When the loan is paid back, the borrowed amount (**principal amount**) and the interest rate are paid back. To calculate simple interest, we use the following equation:

$$I = Pni$$

where

I = the amount of interest paid
P = principal (amount borrowed)

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n = number of years (or period)
i = interest rate

Note: This equation is not listed on the Board of Certified Safety Professionals (BCSP) examination reference sheet.

Example

Your company would like to refit one of its processing lines and has determined that the cost to do so would require $50,000. You are asked to calculate the total cost of the project if the interest rate is 6% annually and the loan is repaid in 3 years. What is the total cost of the project?

$$I = (\$50,000)(3\,\text{years})(0.06\,\text{per year})$$

$$I = \$9000.00.$$

The cost of borrowing $50,000 is $9,000. Add the interest to the principal amount and the total project cost is $59,000.

Compound Interest

Most lenders charge interest by using compound interest methods, which means that in addition to the principal, the amount of interest charged also is charged interest. This addition is called compounding. For example, a loan of $10,000 is charged an interest rate of 5%, which is compounded monthly. Therefore, at the end of the first month, the loan balance would be $10,500. At the end of the second month, the loan balance would be $11,025, assuming there have been no payments to reduce the principal amount. An easy equation to calculate compound interest is as follows:

$$F = P\left(1 + \frac{i}{n}\right)^{nt}$$

where
F = future value of the loan
P = initial loan amount
i = interest rate (expressed in decimal)
n = number of times per year interest is compounded
t = number of years invested

Note: This equation is not listed on the BCSP examination reference sheet but is included to provide you with an understanding of how financial calculations are derived.

Example

Your company has borrowed $10,000 from the lender, who charges an interest rate of 3%, compounded semiannually (twice a year). The loan will run for 3 years. Calculate the entire loan cost.

$$F = \$10,000\left(1+\frac{0.03}{2}\right)^{2(3)}$$

$$F = \$10,000(1.015)^{6}$$

$$F = \$10,000(1.093)$$

$$F = \$10,934.34$$

Therefore, the 3-year loan cost would be $10,934.34.

Future Value of Money

Similar to the compound interest equation, but asking the question in another way, let's look at the future value of the same $10,000. In other words, what is the value of the investment if we were to put the $10,000 into an interest-bearing account at 3% for 3 years? We can calculate this by using the following equation:

$$F = P(1+i)^{n}$$

where
F = future value of money
P = present value of the money (principal)
i = interest rate (annual percentage rate [APR])
n = number of years (in this case, number of years invested)

$$F = \$10,000(1+0.03)^{3}$$

$$F = \$10,000(1.03)^{3}$$

$$F = \$10,927.27$$

Example

Company XYZ has purchased a tract of land for $182,000. What would be the value of this land in 20 years, assuming an APR of 9%?

$$F = \$182,000(1 + 0.09)^{20}$$

$$F = \$182,000(1.09)^{20}$$

$$F = \$1,020,002$$

Loan Balance

Most loans, however, are not based on an end-of-loan payment. Most are made on the terms that you would begin making equal payments throughout the term of the loan. For example, on the basis of the previous scenario, your company borrowed $10,000, you can determine your loan balance at the end of any given year (or period) using the following equation:

$$B = A\left(1 + \frac{i}{n}\right)^{nt} - P\frac{\left(1 + \frac{i}{n}\right)^{nt} - 1}{\left(1 + \frac{i}{n}\right) - 1}$$

where

B = balance after t years
A = original loan amount (principal)
n = number of payments per year
P = amount paid per payment
t = number of years
i = APR

Note: This equation is not listed on the BCSP examination reference sheet but is helpful in determining the loan balances.

Example

Your company has been made a loan of $10,000 from the bank and agrees to make equal installment payments of $100 monthly until the loan is repaid. The APR is 4%. What is the balance at the end of 3 years?

$$B = \$10,000\left(1 + \frac{0.04}{12}\right)^{12(3)} - \$100\frac{\left(1 + \frac{0.04}{12}\right)^{12(3)} - 1}{\left(1 + \frac{0.04}{12}\right) - 1}$$

$$B = \$10{,}000(1.003)^{36} - \$100\frac{1.114 - 1}{1.003 - 1}$$

$$B = \$10{,}000(1.114) - \$100(38)$$

$$B = \$11{,}140 - 3800$$

$$B = \$7340.00$$

If your company repays the loan at \$100 per month for 3 years, the company would still owe \$7340.00 toward the loan.

Time Value of Money

Many times you will be asked to evaluate when an investment will pay for itself, based on savings (i.e., injury/accident prevention, etc.). We can predict the time value of money using the following equation:

$$P = F(1+i)^{-n}$$

where
P = present worth of money (principal)
F = future worth (or savings)
i = annual interest rate (APR) in decimal

Example

If XYZ Corporation makes an investment of \$30,000 to purchase safety equipment and by purchasing this equipment the company predicts it would prevent \$10,000 in injury-related costs, when will the investment pay for itself? The annual interest rate is 12%. To calculate this, you must calculate each year individually, starting with the first year.

$$P = \$10{,}000(1+0.12)^{-1(\text{year}1)}$$

$$P = \$10{,}000(1.12)^{-1}$$

$$P = \$8928.57$$

At the end of 1 year, the value of the investment is $8928.57, leaving a balance of $21,071.43. Therefore, you would continue to calculate for the second year, as follows:

$$P = \$10,000\left(1 + 0.12\right)^{-2(\text{year}2)}$$

$$P = \$10,000\left(1.12\right)^{-2}$$

$$P = \$7971.94$$

At the end of 2 years, the value of the investment is $7971.94 plus the value of year 1 of $8928.57 for a total value of $16,900.51. As you can see, the value of the loan has not paid for itself, so you will need to continue calculating.

$$P = \$10,000(1 + 0.12)^{-3(\text{year}3)}$$

$$P = \$10,000\left(1.12\right)^{-3}$$

$$P = \$7117.80$$

The value of the investment at the end of 3 years is equal to the value of all 3 years combined or $24,018.31. Continue calculating until the original investment of $30,000 has paid for itself.

$$P = \$10,000\left(1+0.12\right)^{-4}$$

$$P = \$10,000\left(1.12\right)^{-4}$$

$$P = \$6255.18$$

The value at the end of 4 years is $30,373.49. Therefore, it would require almost 4 years for the original investment of $30,000 to pay for itself.

Series Compound Amount Factor

To calculate the future value of money, given a series of regular payments, also known as the *series compound amount factor*, we can utilize the following equation:

$$F = A(1 + i)^n$$

where
F = future value of money
A = each payment (amount in $) (end of period)
i = interest rate (APR)
n^{-1} = number of period (in this case, at the end of the first year; if it is 2 years, then we represent it as n^{-2})

or, represented differently, by the equation listed below and on the BCSP examination reference sheet:

$$F = A\left(\frac{(1+i)^n - 1}{i}\right)$$

Example

What would be the future value of a loan if you made equal payments of $100 at the end of the loan period and the interest rate was 8% per year for 3 years?

$$F = 100\left(\frac{(1+0.08)^3 - 1}{0.08}\right)$$

$$F = 100\left(\frac{1.26 - 1}{0.08}\right)$$

$$F = 100(3.25)$$

$$F = \$325$$

Sinking Fund Factor

The *sinking fund factor* is considered to be the inverse of the series compound factor. This equation is used whenever you would like to determine the amount of each payment. This equation is listed below:

$$A = F\left(\frac{i}{\left[(1+i)^n - 1\right]}\right)$$

Example

You have determined that the future value of a loan is $10,285.00 at an interest rate of 7.5% over 3 years. You wish to repay the loan at the end of each year. What are your yearly payments?

$$A = \$10,285\left(\frac{0.075}{\left[\left(1+0.075\right)^{3}-1\right]}\right)$$

$$A = \$10,285\left(\frac{0.075}{\left(1.24\right)-1}\right)$$

$$A = \$10,285\left(0.31\right)$$

$$A = \$3188.35 \text{ per year}$$

Capital Recovery Factor

The *capital recovery factor* is similar to the two previous equations. You may want to know the payment amount based on the present value (or present worth) of the loan given a certain percentage rate. To do this, we utilize the following equation:

$$A = P\left(\frac{i\left(1+i\right)^{n}}{\left(1+i\right)^{n}-1}\right)$$

where

A = period payment amount ($)
P = present worth of money
i = APR in decimal
n = number of periods

Example

You are asked to assist with a capital improvement project that includes numerous safety-related items, such as life safety and NFPA code upgrades. The total cost of the project is estimated by your engineers to be $5,350,800. The owner currently has $640,000 to invest in the project and will need to borrow the remaining funds. There is a 2.5% (of the total loan amount) loan origination fee associated with securing the loan. Determine the amount of money that the company must pay at the end of each year to repay the loan if it is locked in at an annual rate of 6.375%, compounded annually, and loses all of its value in 10 years.

The solution to this problem is multifaceted. The first step would be to determine the total loan needed.

Total project funds needed:	$5,350,800
Company funds ("Down payment")	($640, 000)
Total funding required:	$4,710,800

Now, you must determine the loan amount, based on needed funds of $4,710,800. Remember that you have the loan origination fee, which will also be financed. The loan origination fee is 2.5% of $4,710,800. When added together, the total loan amount will be $4,828,570.

Now, we can insert our data into the equation as follows:

$$A = \$4,828,570\left(\frac{0.06375(1+0.06375)^{10}}{(1+0.06375)^{10}-1}\right)$$

$$A = \$4,828,570\left(\frac{0.118}{0.855}\right)$$

$$A = \$4,828,570(0.138)$$

$$A = \$666,342.66\,\text{per year}$$

Series Present Worth Factor

The *series present worth factor* is the corresponding inverse of the capital recovery factor and is demonstrated in the equation below:

$$P = A\frac{\left[(1+i)^n - 1\right]}{i(1+i)^n}$$

Example

Using the information listed in the capital recovery section, you have secured a loan at 0.575% annual interest, compounded annually, and have agreed to make annual payments of $500,000. How much money will be repaid on this loan at the end of 10 years?

$$P = \$500,000\frac{\left[(1+0.0575)^{10} - 1\right]}{0.0575(1+0.0575)^{10}}$$

$$P = \$500.000\frac{0.749}{0.1}$$

$$P = \$3,745,000$$

Therefore, at the end of 10 years, you have paid $3,745,000 of the $4,828,570 loan, leaving a balance of $1,083,570.

Summary

Engineering economics continues to become an increasing factor in the day-to-day operations of a safety professional. As you can see from the few equations listed in this chapter, the structuring of a loan is an important financial aspect of any business owner or financial manager. In most cases, financial planners will provide the necessary financial information needed to finance a project. However, it is important to know the basic financial information in order for you, as Safety Managers, to justify some of your recommendations. A well-thought-out recommendation will be received in a more favorable light by the final decision-makers.

Reference

1. http://www2.latech.edu/~sajones/Senior%20Design%20Web%20Pages/Homework%207%20on%20Engineering%20Economics.htm.

21

Management Theories

Management in all business areas and human organization activity is the act of getting people together to accomplish desired goals and objectives. Management consists of planning, organizing, staffing, leading or directing, and controlling an organization (a group of one or more people or entities) or effort for the purpose of accomplishing a goal. Safety professionals, at all levels, should have a thorough understanding of management principles, theories, and styles, as they will undoubtedly either become managers or become managed.

There are many management theories in the business world today. In this chapter, the traditional management styles and theories will be discussed. There may be a few questions on the Associate Safety Professional or Certified Safety Professional examinations regarding management theories. Chapter 19 includes discussions on Maslow's Hierarchy of Needs; McGregor's Theory X and Theory Y; Herzberg Motivational Theory; Deming's PDCA model; and Management by Objectives. Safety Management Systems are discussed in Chapter 31.

Management Theories

Maslow's Hierarchy of Needs

In 1943, Abraham Maslow introduced his *Hierarchy of Needs Theory.* In this theory, Maslow proposed that all human beings are motivated by unsatisfied needs and that certain lower factors need to be satisfied before higher needs can be satisfied. Figure 21.1[1] illustrates Maslow's Hierarchy of Needs (represented in pyramid form to illustrate the lower to higher factors).

Maslow theorized that the lower needs must be satisfied before the next need level serves as a motivator. Furthermore, once the lower level need has been satisfied, it no longer serves as a motivator. As a safety professional, it is important to understand this theory and the potential motivation of employees.

Physiological Needs

These needs are obvious, as they are the basic requirements for human survival. Physiological needs include breathing, food, water, sexual activity, homeostasis, and excretion.

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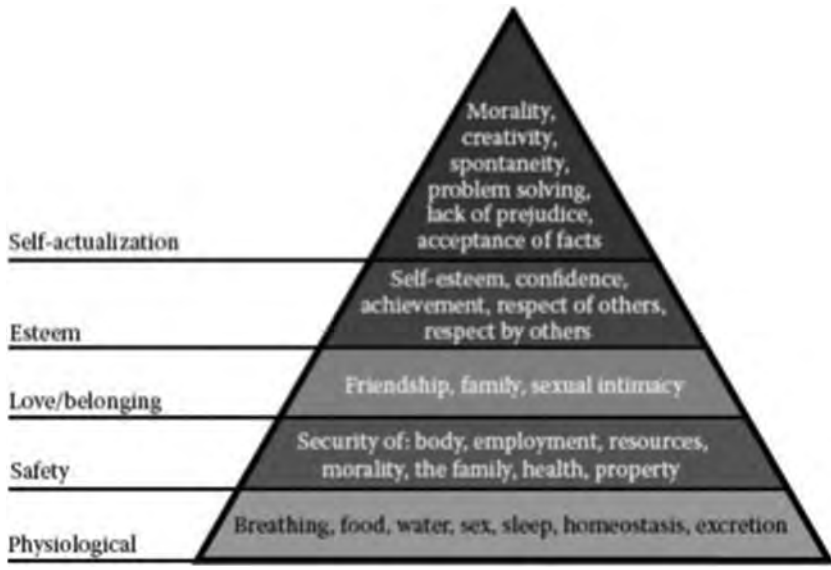


FIGURE 21.1
Maslow's hierarchy of needs (Source: Yates, W. David 2015).

Safety Needs

Once the physiological needs are satisfied, safety and security take precedence and tend to dominate a person's behavior. Safety and security are not limited to physical safety. They also involve the need for a predictable, orderly world where there is very little inconsistency or uncontrollable events, including job security. Safety and security can include

- Personal security
- Financial security
- Health and well-being
- Safety net against accidents/illnesses and their adverse effects

Love and Belonging

This third layer of human needs is social and involves feelings of belonging. This aspect involves emotionally based relationships in general such as

- Friendship
- Intimacy
- Family

Esteem

All humans have a need to be respected and to have self-esteem and self-respect. It represents the basic human desire to be accepted and valued by others. Included in this step is the personal need to contribute and feel appreciated. Esteem is considered an ongoing need.

Self-Actualization

This level represents a person's full potential and the prospect of reaching that potential. In other words, what a person is meant to achieve takes an increasing desire to achieve that potential. In order to reach the level of self-actualization, a person must have all of the lower-level needs met. Once a person has achieved this level, they can accept their own human nature, with all its shortcomings and discrepancies from the ideal image without feeling any real concern. Self-actualized persons tend to focus on solving problems for the good of something greater than themselves. Problems encountered by the self-actualized person are considered only as "a task that they must do." Self-actualization needs are to be considered continuing.

McGregor's Theory X and Theory Y

In 1960, Douglas McGregor announced his two theories of organization management and employee motivation, calling them *Theory X* and *Theory Y*. In both theories, McGregor assumed that the manager's role was to organize resources for the benefit of the company. However, McGregor's characterization of employees and their motivation is quite different between the two theories.[2]

Theory X

In Theory X, McGregor states that leadership assumes the following:

- Work is inherently distasteful to most people, and they will attempt to avoid work whenever possible.
- Most people are not ambitious, have little desire for responsibility, and prefer to be directed.
- Most people have little aptitude for creativity in solving organizational problems.
- Motivation occurs only at the physiological and security levels of Maslow's Hierarchy of Needs.
- Most people are self-centered. As a result, they must be closely controlled and often coerced to achieve organizational objectives.
- Most people resist change.
- Most people are gullible and unintelligent.

To summarize Theory X, McGregor believed that the main source of most employee motivation is monetary, with security as a strong second. The manager of Theory X employees can manage in one of two ways. He or she can manage by coercion, threats, or micromanagement. The other approach is to be permissive with his or her employees and seek harmony. As you can plainly see, neither of these approaches is optimal. The best management method, under this theory, lies somewhere between these two approaches.

Theory Y

In Theory Y, McGregor theorizes that employees are motivated primarily at the esteem and self-actualization levels. Almost in contrast to Theory X, Theory Y leadership makes the following general assumptions:

- Work can be as natural as play if the conditions are favorable.
- People will be self-directed and creative in meeting their work and organizational objectives if they are committed to them.
- People will be committed to their quality and productivity objectives if rewards that address higher needs such as self-fulfillment are in place.
- The capacity for creativity spreads throughout organizations.
- Most people can handle responsibility because creativity and ingenuity are common in the population.
- Under these conditions, people will seek out responsibility.

Under Theory Y, an organization can apply the following scientific management principles to improve employee motivation:

- *Decentralization and delegation*: Decentralize control and reduce the number of management levels required to operate.
- *Job enlargement*: Broadening the scope of an employee's job, which adds variety and opportunities.
- *Participative management*: Organizations consult with employees in the decision-making process.
- *Performance appraisals*: Having employees set objectives and participate in the process of evaluating how well they are met.

Herzberg Motivational Theory

In 1959, Frederick Herzberg introduced his Motivational Theory. In this motivational theory, Herzberg attempted to explain factors that motivate individuals by identifying and satisfying their individual needs, desires, and the aims pursued to satisfy these desires. In his theory, Herzberg stated that

motivation can be split into two major categories: hygiene factors and motivation factors. Hygiene factors affect the level of dissatisfaction but are rarely noted as creators of job satisfaction. However, if these factors are not present or satisfied, they can demotivate a person.[3] Hygiene factors include the following:

- Supervision
- Interpersonal relationships
- Physical working conditions
- Salary

Job dissatisfaction, under normal circumstances, is not normally attributed to motivation factors. However, when they are present, they serve as motivational factors. Motivation factors include

- Achievement
- Advancement
- Recognition
- Responsibility

Whenever there is a shortage of motivation factors present in the work environment, the employee will focus on other factors, such as hygiene factors.

The Deming Cycle

The Deming Cycle, or PDCA cycle is a continuous improvement quality model that consists of four repetitive steps conducted in a logical sequence. The four steps include Plan, Do, Check, and Act. Deming proposed that if these four steps are continuously followed, quality will improve. Figure 21.2[4] illustrates Deming's PDCA Cycle.



FIGURE 21.2
The Deming cycle (PDCA)[5] (Source: Yates, W. David 2019).

Management by Objectives

Peter Drucker first used the term *management by objectives* in 1954. Management by objectives (MBO) is the process of agreeing upon objectives within an organization so that management and employees agree to the objectives and understand what they are in the organization.[4] The main focus of MBO is to set established goals for the organization by allowing both management and employees to participate in the process. By doing this, the employee achieves personal goals and has a direct impact on the success of the organization. Some of the important features and advantages of MBO are as follows:

- *Motivation*: It involves employees in the whole process of goal setting and increases empowerment, employee job satisfaction, and commitment.
- *Improved communication and coordination*: In the MBO process, there are frequent evaluations of the objectives and goals. This evaluation process, which is conducted by both management and employees, assists in maintaining harmonious relationships. When goals are lacking, both employees and management participate in the problem-solving process.
- *Clarity of goals.*

Contingency Theory

Contingency theory is a class of behavioral theory that claims that there is no one best way to organize a corporation, lead a company, or make decisions. Instead, the optimal course of action is contingent upon the internal and external situations.

Systems Theory

Systems theory is an interdisciplinary theory about the nature of complex systems in nature, society, and science and is a framework by which one can investigate or describe any group of objects that work together to produce some result. In this theory, an organization is considered and treated as a system.

Chaos Theory

Chaos theory is a field of study in mathematics, physics, and philosophy that examines the behavior of dynamical systems that are highly sensitive to initial conditions. This sensitivity is popularly referred to as the butterfly effect. Small differences in initial conditions yield widely diverging outcomes for chaotic systems, rendering long-term prediction impossible in general. This happens even though these systems are deterministic, meaning that their

future behavior is fully determined by their initial conditions, with no random elements involved. In other words, the deterministic nature of these systems does not make them predictable.

Scientific Management Theory

Advocated by Frederick Winslow Taylor in 1911, the scientific management theory is predicated on four principles and includes:

- Determining an objective approach to complete a task through constant experimentation.
- Creating a positive environment for employees and employers that results in overall harmony.
- Managers and employees must be involved in decision-making and developing standards.
- Work should be based on a worker's training and ability, along with continued development.

Classical Management Theory

Classical Management Theory is based on a hierarchical structure where decisions are made by top leadership. It is based on the assumption that employees have only financial needs. Management assumes that this financial need is the only consideration, and if they can meet that need, then the motivation aspect has been achieved.

Administrative Management Theory

The Administrative Management Theory, also known as Fayolism, is based on fourteen principles that include:

- Division of labor
- Authority and responsibility
- Discipline
- Unit of command
- Unit of direction
- Subordination of individual interest
- Remuneration
- Degree of centralization
- Scalar chain
- Order
- Equity

- Stability of tenure of personnel
- Esprit de Corps

Human Relations Theory

The Human Relations Theory was first developed by Elton Mayo and looks into human needs, which evolved from the Hawthorne studies. There are four factors involved in this theory, which include:

- Treating employees with a focus on building human relations instead of considering them as production machines.
- Promoting positive values through positive interactions in the work environment.
- Providing effective supervision and removing stress and fatigue of employees.
- Creating a healthier and positive work environment and conditions.

Contingency Management Theory

This theory emerged in the 1970s and was proposed by Fred Fiedler. It is based on the idea that leadership should adapt to any situation. Crucial factors in this theory consist of:

- Structure of work/tasks
- Lead-employee relationship
- Leader's power

He developed a scale where the leader can identify the employee who is the hardest to work with and then rate them.

Bureaucratic Management Theory

This theory was developed by Max Weber and is based on the following six characteristics:

- Hierarchical structure
- Management based on rules
- Specialization of tasks
- Impersonal approach based on rationality
- Career orientation
- Hiring based on employees' ability and skills

Systems Management Theory

Systems Management Theory is based on the approach that considers an organization as having many subsystems. In this theory, the subsystems work together to achieve the goal of the whole.

Management Styles

Managers perform many roles within an organization. How they function in these roles depends entirely on their management style. A management style is the overriding method of leadership used by a manager. The two main categories of management styles include:

- Autocratic
- Permissive

These two styles are in direct contrast to each other. Each can be divided into subgroups, as discussed in the following.

An autocratic leader or manager makes all decisions unilaterally, while the permissive leader permits subordinates to take part in decision-making and gives them a considerable degree of autonomy in completing routine tasks.

Directive Democrat

The directive democrat leader allows subordinates to participate in the decision-making process but closely supervises employees.

Directive Autocrat

The directive autocrat leader makes decisions unilaterally and closely supervises employees.

Permissive Democrat

The permissive democrat leader allows employees to participate in the decision-making process and gives subordinates some latitude in carrying out their work.

Permissive Autocrat

The permissive autocrat leader makes decisions unilaterally but gives employees latitude in carrying out the work.

As you might well imagine, the situation dictates the style of leadership that a manager may wish to employ. Obviously, no one style of management will work in every situation. For example, if you are a leader of military troops that have been assigned to attack a village, you may wish to employ a directive autocrat style of leadership, whereas if you are the manager of a department that is about to undergo significant process changes, it would be advisable to use more of a permissive democrat style of management. The style of management must change with the task or job at hand.

Key Information to Remember on Management Theories

1. Maslow's Hierarchy of Needs includes physiological, safety, belonging, esteem, and self-actualization.
2. McGregor's Theory X states that employees do not want to work and are only motivated by money.
3. McGregor's Theory Y states that employees like to work and, when their needs are met, actually seek out responsibility.
4. Herzberg's Motivation Theory classifies factors into two categories: hygiene factors and motivation factors.
5. The Deming cycle has four steps, which are continuous and include Plan, Do, Check, and Act.
6. Autocratic leaders make decisions unilaterally.
7. Permissive leaders permit participation in the decision-making process.

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22

Accident Causation and Investigation Techniques

Domino Theory

The Domino Theory, also known as Heinrich's Domino Theory, was developed by H.W. Heinrich in 1932 (Figure 22.1).[1] It is considered the first scientific approach to accident prevention. According to Heinrich, an "accident" is one factor in a sequence that may lead to an injury. The factors can be visualized as a series of dominoes standing on edge; when one falls, the linkage required for a chain reaction is completed. Each of the factors is dependent on the preceding factor.

According to the Domino Theory, a personal injury (the final domino) occurs only as a result of an accident. An accident occurs only as a result of a personal or mechanical hazard. Personal and mechanical hazards exist only through the fault of careless persons or poorly designed or improperly maintained equipment. Faults of persons are inherited or acquired as a result of their social environment or acquired by ancestry. The environment is where and how a person was raised and educated. The factor preceding the accident (the unsafe act or the mechanical or physical hazard) should receive the most attention. Heinrich felt that the person responsible at a company for loss control should be interested in all five factors but be concerned primarily with accidents and the proximate causes of those accidents. He also emphasized that accidents, not injuries or property damage, should be the point of attack. He defined an accident as any unplanned, uncontrolled event that *could* result in personal injury or property damage. For example, if a person slips and falls, an injury may or may not result, but an accident has taken place.

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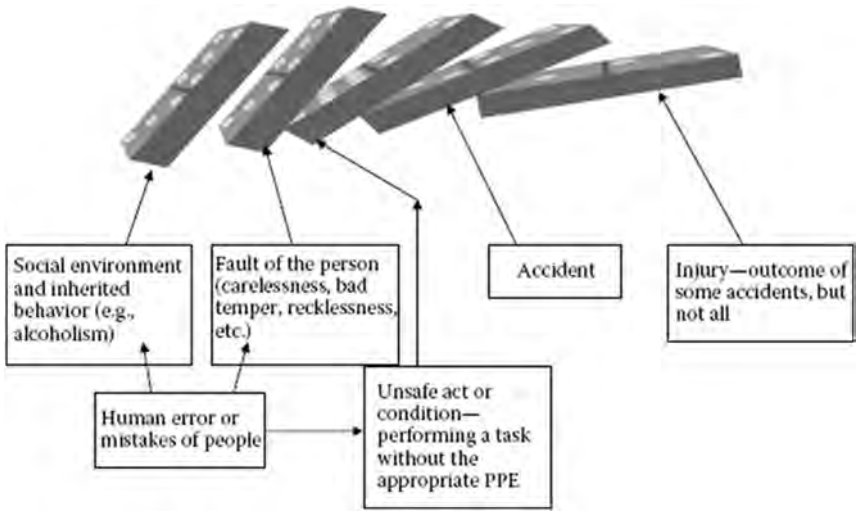


FIGURE 22.1
Graphical representation of the Domino Theory. (Source: From United States Army, 2009; www .armystudyguide.com/content/bm~doc/accident-causation.

Heinrich's Axioms of Industrial Safety

- Injuries result from a complex series of factors, one of which is the accident itself.
- Accidents occur only as a result of an unsafe act by a person or a physical or mechanical hazard.
- Most accidents result from the unsafe behaviors of people.
- Unsafe acts do not always result in an accident/injury.
- Reasons why people doing unsafe acts can aid in corrective action.
- Severity of the accident is largely fortuitous, but the cause is largely preventable.
- Accident prevention techniques are analogous to best quality and production techniques.
- Management should assume responsibility for safety as it is in the best position to get results.
- The supervisor is the key person in accident prevention.
- Any accident results in direct and indirect costs.

In Heinrich's theory, he proposed three corrective sequence actions ("The Three E's") as follows:

- Engineering
- Control hazards through product design or process change
- Education
- Train workers regarding all facets of safety
- Impose on management that attention to safety pays off
- Enforcement
- Ensure that internal and external rules, regulations, and standard operating procedures are followed by workers as well as management

Heinrich concluded that accidents were primarily the result of unsafe acts or unsafe conditions or were unavoidable. In Figure 22.2, we see them presented graphically.

Human Factors Theory

Based on Human Factors Theory, accidents are entirely the result of human error. These errors are categorized broadly as:

- Overload
- The work task is beyond the capability of the worker

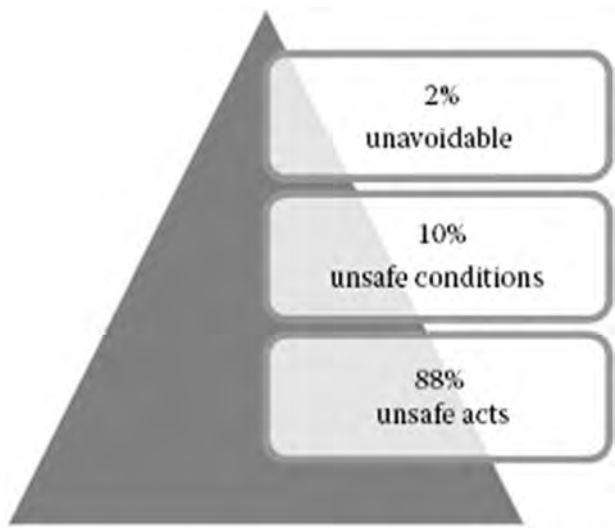


FIGURE 22.2
Heinrich's conclusions (Source: Yates, W. David 2019).

- Environmental factors (noise, distractions, etc.)
- Internal factors (personal problems, emotional stress)
- Situational factors (unclear instructions, risk level)

Worker capacity is measured in terms of productivity or load; be it in the form of manufacturing or clerical load, load can be measured to evaluate one's productivity worth. Many factors affect worker load capacity: natural ability, training, and state of mind are but a few. If these factors affect worker load capacity, overload is reached. Overload is a syndrome where the worker's natural capacity for productivity is overwhelmed. Most often, accidents are a result of worker inexperience or lack of progressive training. Other factors that influence a worker's capacity are fatigue level, stress, and physical conditioning. Noise, climatic lighting, and distractions only add to the overload foundation. Internal factors or limits on the mental state of worker productivity are personal problems, emotional stress, and worry. Situational factors are the physical working environment surrounding workers. These can be stressors such as the level of risk and unclear instructions, or just the novelty of the job can adversely affect worker load.

- Inappropriate worker response
- To hazards and safety measures (workers' fault)
- Detecting a hazard but not correcting it
- Removing safeguards from machines and equipment
- Ignoring safety rules and regulations
- To incompatible workstations (management, environmental faults)
- Ignoring safety rules and regulations for production

How a person responds in a given situation can be the determining factor in whether an accident could be prevented or could lead to the cause of one. If he or she ignores a suspected hazard and does nothing to correct the situation, he or she has responded inappropriately. If a person willingly disregards a safety procedure or circumvents safety locks on equipment, that person has acted with an inappropriate response.

- Inappropriate activities
- Performing tasks without the requisite training
- Misjudging the degree of risk involved with a given task

Human error can be the result of inappropriate activities. Oftentimes, undertaking a task without the requisite training can lead to injuries. Being unfamiliar with equipment and procedures and misjudging the degree of risk associated with the task are examples of inappropriate activities.[2]

Accident and Incident Theory

This theory is also known as *Petersen's Model* or *Petersen's Theory* (Figure 22.3). It is basically an extension of the Human Factors accident causation model. Dan Petersen introduced additional elements such as ergonomic traps, the decision to err, and system failures. He stated that a decision to err by an employee may be unconscious and based on logic, or it could be a conscious decision. Factors such as deadlines, peer pressure, and budget constraints could make a person decide to behave in an unsafe manner. One important factor in the Petersen model that causes a person to make a logical decision to disregard procedures is the "Superman Syndrome." The Superman

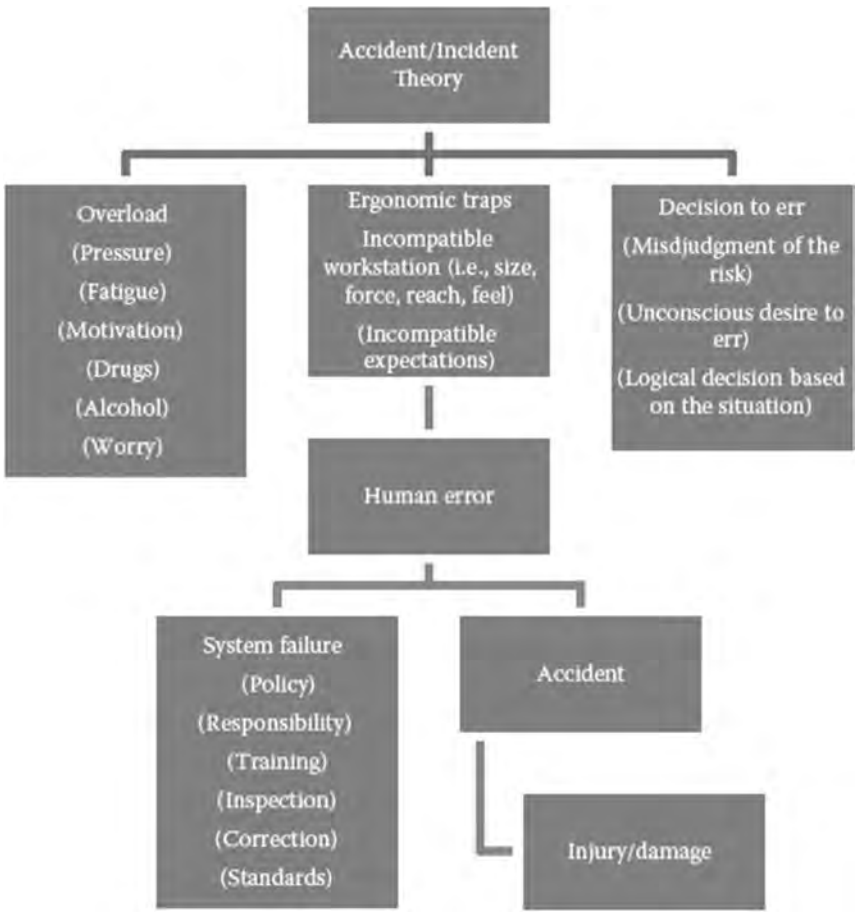


FIGURE 22.3
Petersen's model of the Accident/Incident Theory (Source: Yates, 2019).

Syndrome leads the person to believe that he is invincible or bulletproof, simply because "it won't happen to me or accidents happen to others who don't pay attention."

His addition of *system failure* is an important step in identifying the potential for a causal relationship between management decisions or management behaviors regarding safety. System failure helps establish and solidify management's role in the accident prevention process. It also helps identify the avenues in which the system can fail, such as clearly defining areas of responsibility, inspections, measurements, training, and orientation of employees.

As part of Petersen's subclass of System Failure, management's role is multilayered. Management is responsible for setting policies, placing responsibility, training employees, following up on training and enforcement of policies with inspections to ensure compliance, and finally enforcing standards with corrective actions. If, at any time, management attention is diverted from the system, a failure will occur.[3]

Epidemiological Theory

The Epidemiological Theory focuses primarily on industrial hygiene and the causal relationship between environmental factors and disease. The Epidemiological Theory is appropriate for studying the causal relationships between environmental factors and accidents. The Epidemiological Theory is represented graphically in Figure 22.4.

As seen in the model above, the two key components are pre-dispositional characteristics and situational characteristics. Pre-dispositional characteristics refer to a person is very susceptible to peer pressure. In other words, the person is controlled by the moods and emotional states of others around them. Situational characteristics can best be described as the current state of affairs people are immersed in, whether the situation involves them driving to work or performing a goal-oriented task. When these two characteristics are combined, and a bad decision is made, the outcome is potentially the result of an accident occurrence.

Systems Theory

Looking at Figure 22.5, one can see that the Systems Theory of accident causation is a relationship between man, machine systems, and the surroundings, which function as a unit or a whole (system). Man, while the most

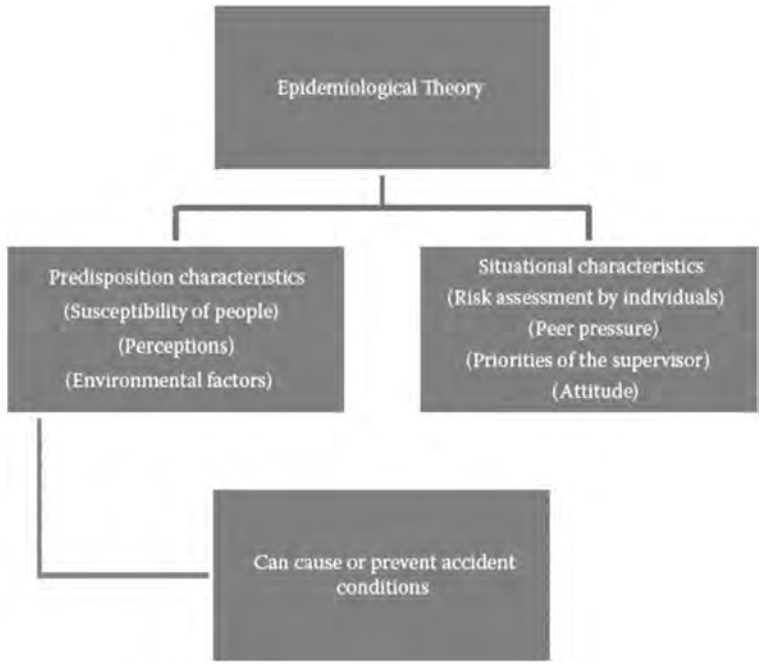


FIGURE 22.4
Epidemiological Theory of accident causation (Source: Yates, W. David 2019).

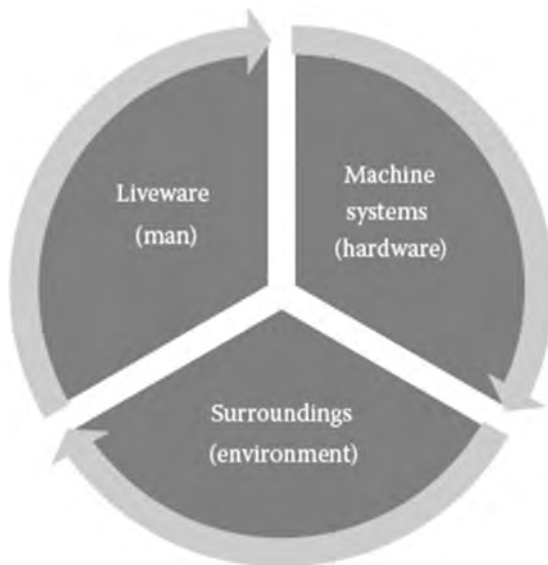


FIGURE 22.5
Systems Theory graphical representation (Source: Yates, W. David 2019).

valuable component of the system, is also the most flexible. The graphical representation shows smooth lines between the relationships. However, it would be better to envision them as jagged lines to account for the wavering attributes/characteristics of man. In the Systems Theory, the *likelihood* of a system failure increases with increasing complexity in the hardware. The *severity* of the potential outcome increases if the time for error correction is short, information to the operator is ambiguous or indirect, and subsystems are interconnected so that one failure can lead to many others in an unpredictable fashion.

Energy Release Theory[4]

William Haddon, a physician and one-time director of the National Highway Transportation Safety Administration, was heavily involved in vehicular safety. As such, he helped impose the following regulations for new cars:

- Seat belts for all occupants
- Energy-absorbing steering column
- Penetration-resistant windshield
- Dual braking systems
- Padded instrument panel
- All measures correspond with the energy and barrier concept.

In the Energy Release Theory, Dr Haddon portrays accidents in terms of energy and transference. This transfer of energy, in large amounts and at rapid rates, can adversely affect living and nonliving object.s, causing injury and damage. Thus, an accident is caused by out-of-control energy. Various techniques, according to this theory, can be employed to reduce accidents, including

- Preventing the buildup of energy
- Reducing the initial amount of energy
- Preventing the release of energy
- Carefully controlling the release of energy
- Separating the energy being released from the living or nonliving object

Behavior Theory

The Behavior Theory is often referred to as *behavior-based safety (BBS)* and has captured an increasing amount of attention recently. There are seven basic principles involved in this theory:

- Intervention
- Identification of internal factors
- Motivation to behave in the desired manner
- Focus on the positive consequences of appropriate behavior
- Application of the scientific method
- Integration of information
- Planned interventions

It is primarily based on a larger scientific field called "organizational behavior." BBS is not a new concept. It has been "tossed around" by many professionals since the 1930s. A BBS program should consist of the following:

- Common goals of the employee and managerial involvement in the process
- Definition of what is expected (clear definitions of target behaviors derived from safety assessments)
- Observational data collection (safety sampling)
- Decisions about how best to proceed based on those data
- Feedback to associates being observed
- Review

Combination Theory

The cause of many accidents cannot be neatly classified into one of the theories mentioned above. The Combination Theory allows a safety professional to use any and all of the theories mentioned in this chapter to determine the root cause or causes of an accident. Using a combination of theories and models may be the optimal approach to problem-solving, by drawing the best conclusions from each of the theories mentioned above.

Modern Causation Model

The modern causation model parallels Heinrich's theory to a certain point (Figure 22.6). Injury is called RESULT, indicating it could involve damage as well as personal injury, and the result can range from no damage to the very severe. The word MISHAP is used rather than Accident to avoid the popular misunderstanding that an accident necessarily involves injury or damage. The term OPERATING ERROR is used instead of Unsafe Act and Unsafe Condition. There are several aspects to the modern causation model, including operating errors, systems defects, command errors, safety program defects, and safety management errors, which will be discussed.

Operating Errors

Examples of operating errors include the following:

- Being in an unsafe position
- Stacking supplies in unstable stacks
- Poor housekeeping
- Removing a guard

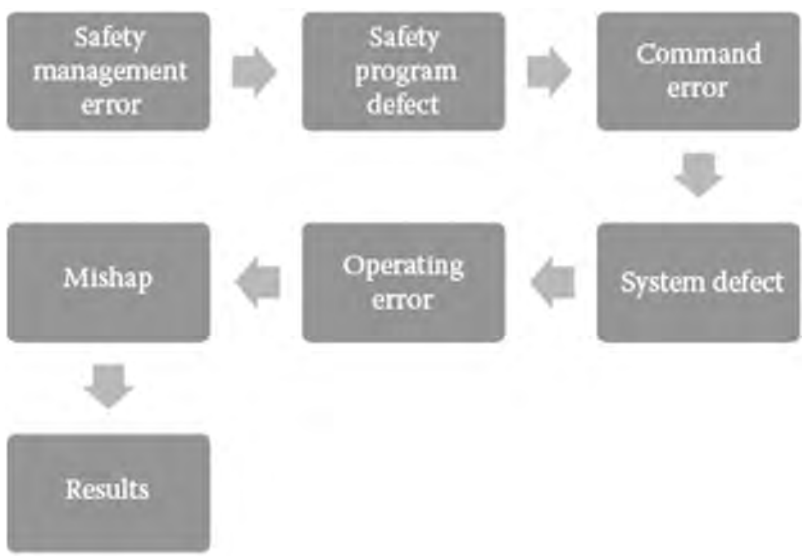


FIGURE 22.6
Modern causation model (Source: Yates, W. David 2019).

System Defects

System defects can be defined as a weakness in the design or operation of a system or program. Examples of system defects include the following:

- Improper assignment of responsibility
- Improper climate of motivation
- Inadequate training and education
- Inadequate equipment and supplies
- Improper procedures for the selection and assignment of personnel
- Improper allocation of funds

Command Error

System defects occur as a result of management or command errors.

Safety Program Defect

A safety program defect is a defect in some aspect of the safety program that allows an avoidable error to exist, such as the following:

- Ineffective information collection
- Weak causation analysis
- Poor countermeasures
- Inadequate implementation procedures
- Inadequate control

Safety Management Errors

Safety management errors are weaknesses in the knowledge or motivation of the safety manager that permit a preventable defect in the safety program to exist.

Seven Avenues

There are seven avenues through which we can initiate countermeasures to a result:

- Safety management error
- Safety program defect

- Management/command error
- System defect
- Operating error
- Mishap
- Result

Countermeasures for each avenue include the following.

Safety Management Error Countermeasures

- Training
- Education
- Motivation
- Task design

Safety Program Defect Countermeasures

- Revise information collection.
- Collection
- Analysis
- Implementation

Command Error Defect Countermeasures

- Training
- Education
- Motivation
- Task design

System Defects Countermeasures

Design revision through

- Standard operating procedures
- Regulations
- Policy letters
- Statements

Operating Errors Countermeasures

- Engineering
- Training
- Motivation

Mishap Countermeasures

- Protective equipment
- Barriers
- Separation

Result Countermeasures

- Containment
- Firefighting
- Rescue
- Evacuation
- First aid

Near-Miss Relationship

In the *near-miss relationship,* initial studies have shown that for each disabling injury, there were 29 minor injuries and 300 close calls/no injury (Figure 22.7). More recent studies indicate that for each serious injury, there are 59 minor injuries and 600 near misses.

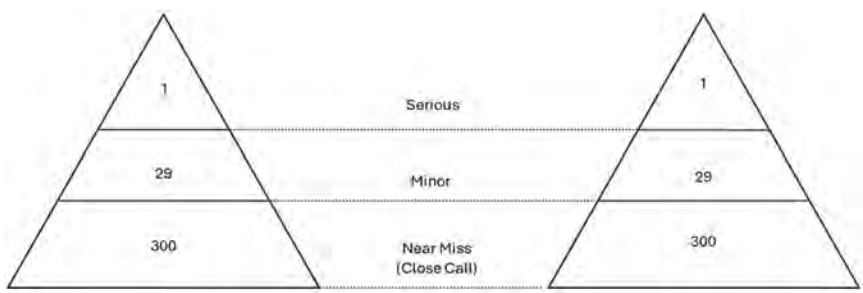


FIGURE 22.7
Near-miss relationship (Source: Yates, W. David 2010).

Accident Investigation Procedures

The type and complexity of any accident determine the particular procedures involved in the investigation. Accident investigations involve common procedures. Those procedures will be discussed in this section. Specific analysis methods will be discussed later in this chapter.

Purpose of the Investigation

The primary purpose of an accident investigation should be to prevent a recurrence of the same accident. It should not be to exonerate individuals or management, satisfy insurance requirements, defend a position for legal argument, or assign blame. All accidents and near-misses (close calls) should be investigated.

Investigation Procedures

1. Secure the scene of the accident, if possible.
   a. Eliminate the hazards.
      i. Control chemicals.
      ii. Deenergize energy sources.
      iii. Shoring, if required.
      iv. Depressurize, if required.
2. Provide care to the injured.
   a. Ensure that medical care is provided to the injured people before proceeding with the investigation.
3. Isolate the scene of the accident.
   a. Barricade the area of the accident and keep everyone out.
   b. The only persons allowed inside the barricade should be Rescue/EMS personnel, law enforcement, and investigators.
   c. Protect the evidence until investigation is completed.
4. Lead investigator selects the team, assigning specific tasks to each member.
5. Present a preliminary briefing to the investigating team, including the following:
   a. Description of the accident, with damage estimates
   b. Normal operating procedures
   c. Maps (local and general)
   d. Location of the accident site

   e. List of witnesses
   f. Events that preceded the accident
6. Visit the accident site to get updated information.
7. Inspect the accident site.
   a. Do not disturb the scene, unless a hazard exists.
   b. Prepare the necessary sketches and photographs. Label each carefully and keep accurate records.
8. Interview each victim and witness. Also, interview those who were present before the accident and those who arrived at the site shortly after the accident. Keep accurate records of each interview. It is recommended that witnesses be interviewed as soon as possible and provide written, signed statements.
9. Determine
   a. What was not normal before the accident?
   b. Where the abnormality occurred?
   c. When it was first noted?
   d. How it occurred?
10. Check each sequence against the data obtained from #9 above.
11. Determine the most likely sequence of events and the most probable cause(s).
12. Conduct a post-investigation briefing.
13. Prepare a summary report, including the recommended actions to prevent reoccurrence.
14. Distribute the report according to your company instructions or guidance procedures.

Fact Finding

Information should be gathered from a variety of sources during the investigation. Information can be obtained from witnesses and reports, as well as observation. Inspect the accident site before any changes occur and verify witness statements. Take photographs and make sketches of the accident scene. Record all information and data accurately. Standard operating procedures are a good source to determine if correct procedures were followed.

Interviews

Interviews should be conducted as soon as possible following an accident. The memories of events are fresher in their minds, and therefore, information

obtained from them can be more valuable. From experience, it is best to get written, signed statements from witnesses as soon as possible, prior to interviewing them. Once the statements have been obtained, the interviewer or interview team should determine a convenient time and location to conduct the interviews. Interviewers should be experienced in interview techniques. The witness should be made to feel comfortable. The lead interviewer should explain the purpose of the investigation and put the witness at ease. Listen carefully to each witness. Let them talk freely. Some member of the interview team should be assigned the task of taking notes, without distracting the witness. Tape recorders should only be used with the knowledge and consent of the witness. Use sketches and diagrams to assist the witness. Emphasize areas of direct observation. Word each question carefully and be sure the witness understands. Identify the qualification of each witness (name, address, occupation, years of experience, etc.). Supply each witness with a copy of his or her statements.

Once all interviews have been completed, the team should analyze them. It is recommended that statements be verified with the actual facts. Sometimes, it may be necessary to "re-interview" some of the witnesses to confirm or clarify key points.

Problem-Solving Techniques (Accident Investigation Techniques)

Accidents represent problems that must be solved through investigations. Several formal procedures solve problems of any degree of complexity. There is no one right or wrong technique. Each accident or accident type will present the best method to use.

The Scientific Method

The scientific method forms the basis of nearly all problem-solving techniques. It is used for conducting research. In its simplest form, it involves the following sequence: making observations, developing hypotheses, and testing the hypotheses.

Even a simple research project may involve many observations. A researcher records all observations immediately. A good investigator must do the same thing. Where possible, the observations should involve quantitative measurements. Quantitative data are often important in later development and testing of the hypotheses. Such measurements may require the use of many instruments in the field as well as in the laboratory.

When making observations, the investigator develops one or more hypotheses that explain the observations. The hypothesis may explain only a few of the observations or it may try to explain all of them. At this stage, the hypothesis is merely a preliminary idea. Even if rejected later, the investigator has a goal toward which to proceed.

Test the hypothesis against the original observations. A series of controlled experiments is often useful in performing this evaluation. If the hypothesis explains all of the observations, testing may be a simple process. If not, either make additional observations, change the hypothesis, or develop additional hypotheses.

As with scientific research, the most difficult part of any investigation is the formulation of worthwhile hypotheses. Use the following three principles to simplify this step:

1. *The principle agreement*: An investigator uses this principle to find one factor that is associated with each observation.
2. *The principle differences*: This principle is based on the idea that variations in observations are due only to differences in one or more factors.
3. *The principle of concomitant variation*: This principle is the most important because it combines the ideas of both of the preceding principles. In using this principle, the investigator is interested in the factors that are common as well as those that are different in the observations.

In using the scientific method, the investigator must be careful to eliminate personal bias. The investigator must be willing to consider a range of alternatives. Finally, he or she must recognize that accidents often result from the chance occurrence of factors that are too numerous to evaluate fully.

Gross Hazard Analysis

Perform a gross hazard analysis (GHA) to get a rough assessment of the risks involved in performing a task. It is "gross" because it requires further study. It is particularly useful in the early stages of an accident investigation in developing hypotheses. A GHA will usually take the form of a logic diagram or table. In either case, it will contain a brief description of the problem or accident and a list of the situations that can lead to a problem. In some cases, analysis goes a step further to determine how the problem could occur. A GHA diagram or table thus shows at a glance the potential causes of an accident. One of the following analysis techniques can then expand upon a GHA.

Job Safety Analysis

Job safety analysis (JSA) is part of many existing accident prevention programs. In general, JSA breaks a job into basic steps and identifies the hazards associated with each step. The JSA also prescribes controls for each hazard. A JSA is a chart listing these steps, hazards, and controls. Review the JSA during the investigation, if a JSA has been conducted for the job involved in

an accident. Perform a JSA if one is not available. Perform a JSA as part of the investigation to determine the events and conditions that led to the accident.

Failure Modes and Effects Analysis

Failure modes and effects analysis (FMEA) determines where failures occurred. Consider all items used in the task involved in the accident. These items include people, equipment, machine parts, materials, and so on. In the usual procedure, FMEA lists each item on a chart. The chart lists the manner or mode in which each item can fail and determines the effects of each failure. Included in the analysis are the effects on other items and on overall task performance. In addition, make evaluations about the risks associated with each failure. That is, project the chance of each failure and the severity of its effects. Determine the most likely failures that led to the accident. This is done by comparing these projected effects and risks with actual accident results.

An example of FMEA is shown in Table 22.1.

Fault Tree Analysis

Fault tree analysis is a logic diagram. It shows all the potential causes of an accident or other undesired event. The undesired event is at the top of a "tree." Reasoning backward from this event, determine the circumstances that can lead to the problem. These circumstances are then broken down into

TABLE 22.1

Example of FMEA

#	Component Description	Failure Mode	Effects	Means of Detection and Safeguards	Actions and Recommendations
1	Master cylinder for brakes in auto	No brake fluid Piston sticks in closed position	No braking when main brake pedal is pressed Brakes lock	Emergency brake lever/handle	Add fluid level indicator Scheduled inspection and maintenance every 12 months
2	Impact sensor in auto airbag system	No signal to airbag on impact Spurious signal to airbag	Airbag doesn't inflate No protection for driver Airbag inflates at the wrong time	System malfunction warning light 2 out of 3 voting logic for airbag deployment	Include redundant sensors Add sensor testing to 20,000 km service schedule

the events that can lead to them, and so on. Continue the process until the identification of all events can produce the undesired event. Use a logic tree to describe each of these events and the way they combine. This information determines the most probable sequence of events that led to the accident. Fault tree diagrams use a graphic model of the pathways within a system that can lead to a foreseeable, undesirable loss event (or a failure). The pathways interconnect contributory events and conditions, using standard logic symbols (AND, OR, etc.). The basic constructs in a fault tree diagram are gates and events. The more common symbols of a fault tree diagram are shown in Table 22.2.

While fault tree diagrams can become very detailed in more complicated systems, the example shown in Figure 22.8 demonstrates a simple car collision at an intersection.

Multilinear Events Sequencing Method

The multilinear events sequencing (MES) method, conceived by Ludwig Benner, is an integrated body of concepts and procedures for investigating and analyzing a wide range of desired and undesired processes before or after they happen. It can best be viewed as a process investigation and analysis method.

The MES method uses a timeline chart to display the sequence of events that contributed to or was the direct cause of the accident (Figure 22.9). Every event is a single action by a single actor. The actor is something that brings

TABLE 22.2

Common Fault Tree Design Symbols

Name of Gate	FTD Symbol	Description
AND		The output event occurs if all input events occur.
OR		The output event occurs if at least one of the input events occurs.
Voting OR (k-out-of-n)		The output event occurs if k or more of the input events occur.
Inhibit		The input event occurs if all input events occur and an additional conditional event occurs.
Priority AND		The output event occurs if all input events occur in a specific sequence.
XOR		The output event occurs if exactly one input event occurs.

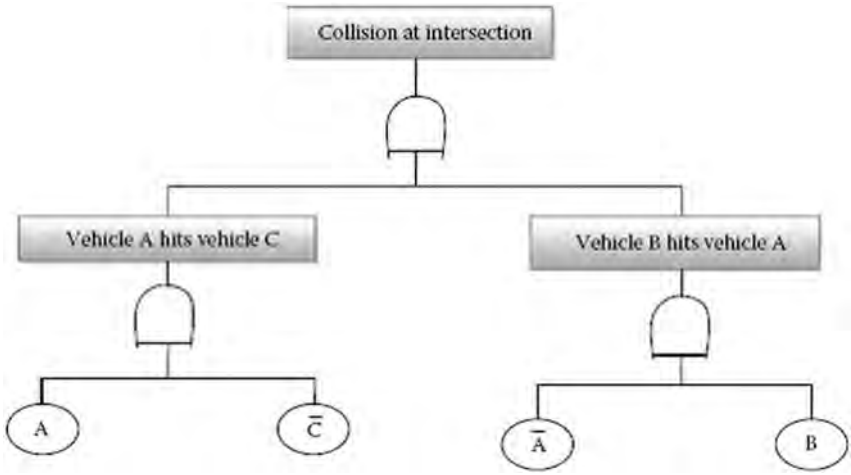


FIGURE 22.8
Example of a fault tree diagram (Source: Yates, W. David 2015).

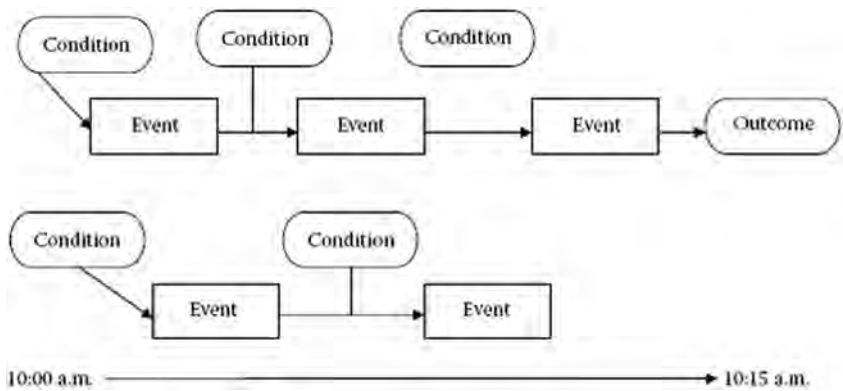


FIGURE 22.9
Example of an MES chart (Source: Yates, W. David 2015).

about events, while actions are acts performed by the actor. A timeline is displayed at the bottom of the chart to show the timing sequence of the events while conditions that influence the events are inserted in the time flow in logical order to show the flow relationship. With this chart, countermeasures can be formulated by examination of each individual event to see where changes can be introduced to alter the process.

Report of Investigation

An accident investigation is not complete until a report is prepared and submitted to the proper authorities, such as the company president. A final report should be prepared to include the following sections:

- Cover page
- Title page
- Executive summary
- Table of contents
- Narrative (body)
- Conclusions and recommendations

The following outline for the Narrative or Text Body is useful in developing the report:

- Background information
- Where and when the accident occurred?
- Who and what were involved?
- Operating personnel and other witnesses
- Account of the accident (what happened?)
- Sequence of events
- Extent of damage
- Accident type
- Source of energy or hazardous materials involved
- Discussion (analysis of the accident—how/why)
- Direct causes (energy sources, hazardous materials)
- Indirect causes (unsafe acts and conditions)
- Basic causes (management policies, personal or environmental factors)
- Recommendations to prevent a recurrence for immediate and long-range action to remedy
- Direct causes
- Indirect causes
- Basic causes
- Summary

Key Information to Remember on Accident Causation and Investigation Techniques

1. The primary purpose of an accident investigation is to prevent the recurrence of the same event.
2. The Domino Theory, also known as Heinrich's Domino Theory, is considered the first scientific approach to accident prevention.
3. According to Heinrich, an injury is caused by the social environment and inherited behavior, fault of the person, unsafe acts or conditions, and a resulting accident.
4. Injuries result from a complex series of factors, one of which is the accident itself (Heinrich's Domino Theory).
5. Heinrich's "Three E's" are Engineering, Education, and Enforcement.
6. Heinrich's conclusions are that 2% of accidents are unavoidable, 10% are attributed to unsafe conditions, and 88% are attributed to unsafe acts.
7. The Human Factors Theory states that all accidents are the result of human error, categorized as overload, inappropriate worker response, or inappropriate activities.
8. Petersen's Accident/Incident Theory is a basic extension of the Human Factors Theory, except that he introduced ergonomic traps and that a decision to err may be based on logic.
9. The Epidemiological Theory focuses primarily on industrial hygiene aspects.
10. The Systems Theory states that there is a relationship between man, machine systems, and the surroundings that make up a whole system.
11. The Energy Release Theory, developed by William Haddon, portrays accidents in terms of energy and transference.
12. Behavior Theory is also known as behavior-based safety.
13. The Combination Theory allows an investigator to use parts or all of any of the theories to solve a problem.
14. The modern causation model uses a series of seven avenues to demonstrate the cause of accidents: safety management error, safety program defect, command error, system defect, operating error, mishap, and results.

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23

Workers' Compensation

Worker compensation laws have been implemented in each state and are specific to that state. The laws of each state vary in so many ways that it would be impossible to discuss each of them individually. Therefore, the intent of this chapter is to provide the reader with a basic understanding of workers' compensation law. Practicing safety professional are heavily involved in major aspects of the workers' compensation program. This involvement includes such activities as submitting the "First Report of Injury"; liaison between the insurance carrier and injured employees; coordination with Human Resources; accident investigations; and case management until the injured employee returns to work without restrictions. The responsibility to ensure employees receive the appropriate care and compensation should be at the forefront of any safety professional's role.

Most states require that employers with five or more employees maintain workers' compensation insurance or prove financial stability for self-insurance. Workers' compensation laws provide employees who are injured or disabled on the job fixed monetary awards, without having to endure litigation. Benefits are also provided for dependents of those workers who are killed because of work-related injuries or illnesses. In addition, it is designed to protect employers and coworkers by limiting recovery amounts and liabilities of both the employers and coworkers. Both state and federal workers' compensation statutes provide this structure. Chapter 23 provides a basic overview of workers compensation laws.

History of Workers' Compensation in the United States

Workers' Compensation (formerly referred to as Workmen's Compensation) as a legal issue emerged in the United States in the early 1900s. Prior to the establishment of codified workers' compensation laws, the only compensation or remedy for an injured employee was to bring a negligence suit against his or her employer. If the employee won the suit, then he or she was compensated for damages, including pain and suffering. It must also be mentioned that during this time, there was a significant increase in the legal profession. Oftentimes, these damages were substantial in nature. The major drawback to this type of remedy was that the employee had to prove

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negligence on the part of the employer, which was sometimes difficult to do. In addition, the employer used several legal defenses, which included

- *Assumption of risk*: The employees accepted the risk they were facing when they accepted the job. By doing so, they gave up any right to collect compensation for injuries.
- *Contributory negligence*: Since the employees contributed to their injuries, regardless of how little, the employees are not permitted to recover compensation for their injuries.
- *Fellow-servant rule*: The employer is not at fault because the accident was the fault of another employee or other employees.

After the implementation of workmen's compensation laws, these three common defenses were eliminated by each state.[1]

The very first workmen's compensation law passed in the United States was the Federal Employer's Liability Act. It was adopted in 1908 and signed into law by President Theodore Roosevelt. He was instrumental in getting this law passed because he demonstrated to Congress that "the entire burden of an accident fell upon the helpless man, his wife and children" and that was "an outrage."

In 1911, the State of Wisconsin passed the first official state law covering workers' compensation in the United States. In this legislation, the employer agreed to provide medical and indemnity (wage replacement) benefits and the injured employee agreed to give up his or her right to sue the employer. Pressure was now on the business community as a result of increasing awards to injured employees. Also, in 1911, 10 more states enacted "workmen's compensation" laws. By 1948, all 48 states and the territories of Hawaii and Alaska had implemented some form of workmen's compensation law. Today, workers' compensation is the exclusive remedy for the injured worker. These laws also protect employers from damage suits filed by the injured worker, as well as providing employers with a basis for calculating production costs.

Current Workers' Compensation Laws

In these workers' compensation laws, most states have prohibited employees from suing businesses that comply with them, except for deliberate assaults and conditions so flagrantly unsafe as to make injury virtually certain. This has been a win/win situation for a number of years. Lately, however, employees have retained attorneys who use this loophole to successfully sue an employer for increased compensation. In these cases, the employee repays the workers' compensation fund for the money already received. These cases are successful primarily because of sympathetic juries who see employers

as an endless source of money and the fact that attorneys work on a "contingency fee," meaning that if no award is made, then the attorney collects no fee. While this practice is in direct conflict with the spirit of the workers' compensation laws, it is one of the major flaws in today's system.

If an employee is injured in a work-related accident, he or she must undergo a waiting period of 3–14 days, depending on the state law. Benefits are typically limited to two-thirds of the employee's wages with a cap, which is also dependent on the state. Injured employees living on two-thirds of their wages will suffer a significant decrease in their standard of living, and therefore, litigation becomes more attractive. On the other hand, if full wages were paid, the employee would be reluctant to return to work. It has been determined that even at two-thirds of their wages, some employees have been found to be malingering so that they can receive benefits without working.

Injuries are placed into one of the four categories listed below:

- *Partial*: when the employee can still work but is unable to perform all duties of the job because of the injury, as would often be the case with a broken finger or a severed toe.
- *Total*: when the employee is unable to work or perform substantial duties on the job, as would often be the case with a severe back injury or blindness.
- *Temporary*: when the employee is expected to fully recover, as would be the case with a broken limb or a sprain.
- *Permanent*: when the employee will suffer the effects of the injury from now on, as would be the case with a severed limb, blindness, or permanent hearing loss.

Coverage Exemptions

The following employees are exempt from the coverage of workers' compensation:

- Any person employed as a domestic servant in a private home
- Any person employed for not exceeding 20 consecutive workdays in or about the private home of the employer
- Any person performing services in return for aid or sustenance only, received from any religious or charitable organization
- Any person employed in agriculture
- Any person participating as a driver or passenger in a voluntary vanpool or carpool program while that person is on the way to or from their place of employment
- Any person who would otherwise be covered but elects not to be covered

Workers' Compensation Premiums

Workers' compensation insurance premiums represent a significant line item on any business' profit and loss statement. Therefore, it is necessary to keep these costs to a bare minimum. Today's safety professional is, or should be, heavily involved in the insurance carrier selection process. In order to do this, you should have some knowledge of how the premiums are calculated. On the surface, the calculation seems simple. However, the truth is that it is anything but simple. Historically, workers' compensation premiums were calculated using the Standard Industrial Classification codes for a particular business or industry. Workers' compensation premiums are usually expressed in dollars per $100 of payroll. Insurance companies that provide workers' compensation coverage now use an additional multiplier known as the *Experience Modification Rate (EMR)* or *Experience Modification Factor (EMF)* to assist in the determination of the cost of workers' compensation costs.

Calculating Experience Modification Rates

The EMR is not simply a comparison of actual losses with expected losses. If premiums were based solely on prior losses, the average insured would pay no premiums after a loss-free period. A period is usually a rolling, 3-year average. Contrary to this, they would pay huge premiums after a major accident involving their employees. In addition, only part of the premium goes to paying losses. The insurance company has expenses that involve underwriting and marketing, which must be paid for.

The experience modification formula is summarized as follows:

$$\text{Experience Modification Rate} = \frac{\text{Adjusted Actual Losses} + \text{Ballast}}{\text{Expected Losses} + \text{Ballast}}$$

These terms are defined below:

Adjusted actual losses: Adjusted actual losses are determined by an additional formula that has a stabilizing effect on the resulting value. The stabilizing effect is accomplished by (1) separating actual losses into primary losses and excess losses and then using only a percentage of excess losses in the computation, and (2) including a portion of the insured's expected losses in the computation. Limiting the amount of excess losses has a moderating effect if the insured suffers an unusually high level of losses during the experience period. Including a portion of the insured's expected losses guarantees that no insured can have a zero modification. Even if the insured has no actual losses

during the experience period, the formula will always produce an adjusted actual loss value greater than zero because a portion of the adjusted losses is calculated as a percentage of expected losses, not just the insured's actual losses.

Expected losses: Expected losses are calculated by multiplying the payrolls in each applicable classification of the insured's employees by an expected loss ratio factor published for each classification in each state.

Ballast: Ballast is an amount that is added to both the numerator and denominator of the experience modification formula to dampen the swings between large credits and large debits. The result is that all modifications come closer to a modification factor of 1.0, also known as "unity modification." A unity modification means that no credit or debit is applied to the insured's rates.

It is particularly important that each employee not be classified into a single category. Office personnel do not have the same risks (expected losses) as, say, an over-the-road driver. Therefore, when requesting coverage by an insurance carrier, businesses must conduct a thorough analysis of the job classifications for each employee.

In recent years, I have experienced a tightening of client requirements that include such provisions in the contract that a vendor must maintain an EMR of 1.0 or below. I have even experienced some clients requiring an EMR of less than or equal to 0.90. Therefore, the EMR becomes more important than just determining the cost of insurance premiums.

Waiver of Subrogation

In recent years, contracts have required a waiver of subrogation statement be put on certificates of insurance before a company is allowed to work on a host employer site. To accommodate this requirement, the *Waiver of Our Right to Recover from Others Endorsement* provides that the insurer will not enforce its right to recover against organizations listed in the endorsement's schedule when the insured is performing work under a contract that requires a waiver. Insurers usually charge an additional premium for providing this waiver. In a few states, contractual waiver of subrogation is prohibited by statute, rendering the endorsement invalid.

Safety Professional's Role and Responsibilities in Workers' Compensation

The primary role or responsibility that a safety professional has in relation to workers' compensation is to ensure that there exists a viable safety program

that ensures the safety and health of employees. Depending on the size of the company, the safety professional may also be called upon to report injuries and file insurance claims, manage injury cases, and coordinate a return-to-work program.

Reporting of Injuries and Claims

Each individual insurance carrier will have its own specific reporting requirements. However, in general, each claim will use a Form 45-Employer's First Report of Injury. This First Report of Injury should be completed and filed at the earliest opportunity. Each carrier will also provide a claim reporting number once a policy has been issued. It is advisable to report all injuries, regardless of the intention to file a claim. For example, an employee has a minor sprain to the ankle. The physician advises the employer that the employee is to be on light or limited duty for 3 days, but that a full recovery is expected. The employer elects to pay the medical expenses out-of-pocket, without filing an insurance claim. This injury should still be reported to the insurance carrier as "FOR RECORD ONLY." This type of reporting does not increase your future premiums but does put the carrier on notice in case the injury goes beyond initial first aid.

When reporting a claim, the following information should be available:

- Employer's FEIN
- Employer's name and address
- Injured employee's full name and address
- Injured employee's date of birth
- Injured employee's date of hire
- Injured employee's specific job title
- Date and time of accident
- Time injured employee began work on the date of the accident
- General description of the accident (where, how, when, what, etc.)
- Name, address, and telephone number of the treating physician or health care provider

It is important for the safety professional to develop a personal relationship and trust with the insurance carrier or agent. The carrier or agent can be a valuable resource in how to manage many complex cases. If there are some questionable reports of injuries by employees or additional information available, the insurance carrier should be notified at the time of claim filing or as soon as possible after discovery.

Case Management

Prompt Reporting

Managing workers' compensation claims begins with prompt reporting of the injury to the insurance carrier. Statistics show that claims reported late cost, on average, 60% more than claims reported early. The majority of carriers have a 24-h claim reporting number.

It is well documented that lost-time accidents and injuries cost substantially more than accidents and injuries that result in no lost time. The workers' compensation carrier will incur the cost of medical expenses and wage loss. The employer, however, incurs hidden costs, consisting of loss of production, reduced employee morale, and possibly loss of customers. Each of these items is not covered under the insurance. One of the best ways to manage workers' compensation costs is to develop a Return-To-Work/Light Duty Policy/Program for your specific company.

Return-to-Work/Light Duty Program

A return-to-work/light duty program is a program to enhance the injured employee's rehabilitation and facilitate his or her return to normal job duties by providing temporary modified work. Some of the employee benefits of a return-to-work/light duty program are as follows:

- Generally, it gets employees back to work 50% faster
- Speeds up recovery up to three times
- Reduces vocational rehabilitation
- Reduces the degree of permanent partial disability
- Reduces the possibility of reinjury upon return
- Employee's wage loss drastically minimized (full wages vs. 66.7%)

The employer benefits of a return-to-work/light duty program are as follows:

- Helps control medical costs by as much as 70%
- Reduces indemnity costs
- Less abuse of the workers' compensation system
- Improves morale/employee relations
- Improved work ethic
- Enhanced company image
- Less litigation

The specifics of the return-to-work/light duty policy/program depend entirely on the restrictions placed on the employee by the medical provider. As one might well imagine, not every injury is the same, which makes it difficult to write the policy specifics. However, an effective return-to-work/light duty program involves the following:

- Identification of potential jobs for modified duty
- Early reporting of injuries and illnesses
- Accident investigation
- Communications between the employer, the injured employee, the medical provider, and the insurance company
- Education of employees and supervisors

The importance of communication between the employer, employee, medical provider, and insurance company. cannot be overstated. It is essential that a trusting relationship be established with the medical provider. The medical provider's main focus should be to ensure that the injured employee is treated promptly and properly. His or her secondary focus is to assist in returning to work as soon as possible. If a medical provider does not trust that an employer will strictly adhere to the work restrictions placed on an employee, the provider may have a tendency to keep the injured employee on full restrictions longer than necessary. A written policy goes a long way in reassuring the medical provider that you have the best interest of the employee in mind.

The return-to-work/light duty program should be put in writing and communicated to all employees. When communicating the program/policy to the employees, it is helpful to emphasize the company's commitment to getting injured employees back to productive work as quickly as possible.

Key Information to Remember on Workers' Compensation

1. Most states require employers with five or more employees to maintain workers' compensation insurance or be self-insured.
2. The first state to pass a workers' compensation law was Wisconsin, which enacted a law in 1911. Ten additional states passed laws in the same year.
3. By 1948, all 48 states and two territories (Alaska and Hawaii) had enacted workers' compensation laws.
4. Work-related injuries are classified into four main categories: partial, total, temporary, and permanent.
5. Workers' compensation insurance premiums are based on dollars per $100 of payroll and an experience modification rate or factor.
6. A return-to-work/light duty program can be one of the most effective tools in reducing workers' compensation premiums and experience modification rates.

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24

Ergonomics

Any safety professional will undoubtedly, encounter low back pain and work-related strains throughout their careers. Despite best efforts at controlling these injuries, they still account for a significant proportion of employee injuries and economic cost to the employer. A significant amount of energy is or will be spent in attempting to develop and implement programs to prevent these types of injuries. Ergonomics plays an important role in the prevention of strains, injuries, and repetitive motion disorders. The International Ergonomics Association defines ergonomics as follows: Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

One of the first professional societies in the field of ergonomics was the Ergonomics Research Society in the United Kingdom, which was started in 1949. This society later became the Ergonomics Society. In 1959, the European Productivity Agency's steering committee on ergonomics became known as "International Ergonomics Association."[1]

There are numerous and varied subdisciplines within the field of ergonomics. This chapter will focus primarily on the National Institute for Occupational Safety and Health (NIOSH) Lifting Equation. The chapter will also provide various examples of ergonomic-related issues and calculations by demonstrating the use of the ergonomic job hazard analysis worksheet.

Definitions

Before proceeding, it is first necessary to understand some of the basic ergonomic terminologies.

Recommended weight limit (*RWL*):[2] The RWL is the primary product in the NIOSH lifting equation. It is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers can perform over a substantial period (e.g., up to 8 h) without an increased risk of developing lifting-related low back pain or injury.

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Lifting index:[2] The lifting index is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship between the weight of the load lifted and the RWL.

Lifting task:[2] The act of manually grasping an object of definable size and mass with two hands and vertically moving the object without mechanical assistance.

Load weight (*L*):[2] Weight of the object to be lifted, in pounds or kilograms, including the container.

Horizontal location (*H*):[2] Distance of the hands away from the midpoint between the ankles, in inches or centimeters (measured at the origin and destination of the lift).

Vertical location (*V*):[2] Distance of the hands above the floor, in inches or centimeters (measured at the origin and destination of lift).

Vertical travel distance (*D*):[2] Absolute value of the difference between the vertical heights at the destination and the origin of the lift, in inches or centimeters.

Asymmetry angle (A):[2] Angular measure of how far the object is displaced from the front (midsagittal plane) of the worker's body at the beginning or ending of the lift, in degrees (measured at the origin and destination of the lift). The asymmetry angle is defined by the location of the load relative to the worker's midsagittal plane, as defined by the neutral body posture, rather than the position of the feet or the extent of body twist (see Figure 24.1).

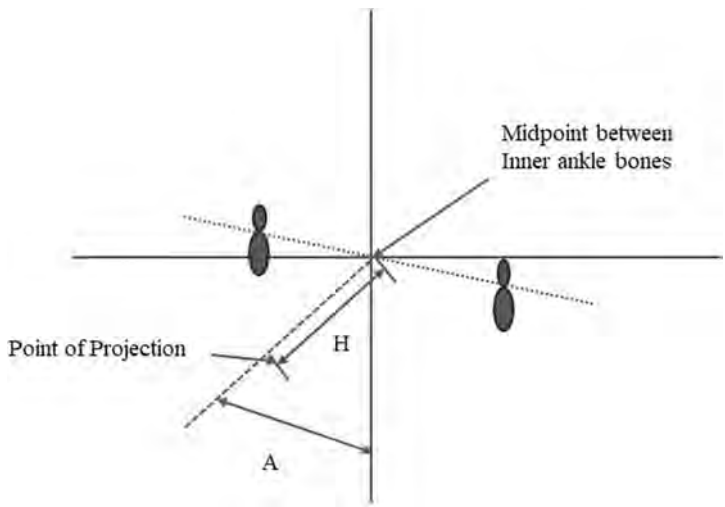


FIGURE 24.1
Top view of sagittal line (Source: From DHHS [NIOSH] Publication No. 94-110).

Neutral body position:[2] Describes the position of the body when the hands are directly in front of the body and there is minimal twisting at the legs, torso, or shoulders.

Lifting frequency (*F*):[2] Average number of lifts per minute over a 15-min period.

Lifting duration:[2] Three-tiered classification of lifting duration specified by the distribution of work time and recovery time (work pattern). Duration is classified as either short (1 h), moderate (1–2 h), or long (2–8 h), depending on the work pattern.

Coupling classification:[2] Classification of the quality of the hand-to-object coupling (e.g., handle, cutout, or grip). Coupling quality is classified as good, fair, or poor.

Significant control:[2] Significant control is defined as a condition requiring precise placement of the load at the destination of the lift. This is usually the case when (1) the worker has to regrasp the load near the destination of the lift, (2) the worker has to momentarily hold the object at the destination, or (3) the worker has to carefully position or guide the load at the destination.

NIOSH Lifting Index[2]

The lifting equation is a tool for assessing the physical stress of two-handed manual lifting tasks. As with any tool, its application is limited to those conditions for which it was designed. Specifically, the lifting equation was designed to meet specific lifting-related criteria that encompass biomechanical, work physiology, and psychophysical assumptions and data. The revised NIOSH lifting equation is based on the assumption that manual handling activities other than lifting are minimal and do not require significant energy expenditure, especially when repetitive lifting tasks are performed. Examples of non-lifting tasks include holding, pushing, pulling, carrying, walking, and climbing. If such non-lifting activities account for more than approximately 10% of the total worker activity, then measures of workers' energy expenditure and heart rate may be required to assess the metabolic demands of the different tasks.

The NIOSH lifting equation is listed as follows:

$$\mathrm{RWL} = \mathrm{LC} \times \mathrm{HM} \times \mathrm{VM} \times \mathrm{DM} \times \mathrm{AM} \times \mathrm{FM} \times \mathrm{CM}$$

The NIOSH lifting equation for metric measurements is as follows:

$$\mathrm{RWL(kg)} = (23)\left(\frac{25}{H}\right)\left[1 - 0.003|V - 75|\right]$$

$$\left[0.82 + \left(\frac{4.5}{D}\right)\right](1 - 0.0032A)(\mathrm{FM})(\mathrm{CM})$$

The NIOSH lifting equation for the US system is as follows:

$$\mathrm{RWL(lb)} = (51)\left(\frac{10}{H}\right)\left[1 - \left(0.0045|V - 30|\right)\right]\left[0.82 + \left(\frac{1.8}{D}\right)\right]$$

$$\times(1 - 0.0032A)(\mathrm{FM})(\mathrm{CM})$$

where the following standards are shown in Table 24.1.

The term *multiplier* refers to the reduction coefficients in the equation. To obtain the multipliers from the appropriate table or computation, it may be necessary to interpolate. For example, when the measured frequency is not a whole number, the appropriate multiplier must be interpolated between the frequency values in the table for the two values that are closest to the actual frequency.

TABLE 24.1

NIOSH Lifting Equation Standards

Symbol	Meaning	Metric System	US System
RWL	Recommended weight limit	kg	lb
LC	Load constant	23 kg	51 lb
HM	Horizontal multiplier	25/h See Table 24.2	10/h See Table 24.2
VM	Vertical multiplier	1 – (0.003 | V – 75 |) See Table 24.3	1 – (0.0075 | V – 30 |) See Table 24.3
DM	Distance multiplier	$0.82 + \left(\frac{4.5}{D}\right)$ D = distance in centimeters See Table 24.4	$0.82 + \left(\frac{1.8}{D}\right)4$ D = distance in inches See Table 22.4
AM	Asymmetric multiplier	1 – (0.0032A) See Table 24.5	1 – (0.0032A) See Table 24.5
FM	Frequency multiplier	See Table 24.6	See Table 24.6
CM	Coupling multiplier	See Table 24.7	See Table 24.7

Horizontal Component[2]

As mentioned previously in the Definitions section, the horizontal location is measured from the midpoint of the line joining the inner ankle bones to a point projected on the floor directly below the midpoint of the hand grasps (load center). In some cases, the *H* value cannot be measured. In these cases, the *H* value can be approximated using the following equation(s):

Metric (H value) estimation equation (all distances in centimeters):

$$H = 20 + \frac{W}{2} \; for \; V \geq 25\,\text{cm}$$

or

$$H = 25 + \frac{W}{2} \; \text{for} \; V < 25\,\text{cm}$$

where

W = the width of the container in the sagittal plane
V = the vertical location of the hands from the floor

US system (H value) estimation equation (all distances in inches):

$$H = 8 + \frac{W}{2} \; \text{for} \; V \geq 10\,\text{in.}$$

or

$$H = 10 + \frac{W}{2} \; \text{for} \; V < 10\,\text{in.}$$

Horizontal Multiplier

See Table 24.2.

Vertical Component[2]

In the Definitions section, we defined the vertical location as the vertical height of the hands above the floor. The vertical location (*V*) is measured vertically from the floor to the midpoint between the hand grasps, as defined by the large middle knuckle.

TABLE 24.2

Horizontal Multiplier

Metric System		US System	
H (cm)	**HM**	**H (in.)**	**HM**
≤25	1.00	≤10	1.00
28	0.89	11	0.91
30	0.83	12	0.83
32	0.78	13	0.77
34	0.74	14	0.71
36	0.69	15	0.67
38	0.66	16	0.63
40	0.63	17	0.59
42	0.60	18	0.56
44	0.57	19	0.53
46	0.54	20	0.50
48	0.52	21	0.48
50	0.50	22	0.46
52	0.48	23	0.44
54	0.46	24	0.42
56	0.45	25	0.40
58	0.43	>25	0.00
60	0.42		
63	0.40		
>63	0.00		

Source: Developed from DHHS (NIOSH) Publication No. 94-110.

Vertical Multiplier

See Table 24.3.

Distance Component[2]

The vertical travel distance variable (*D*) is defined as the vertical travel distance of the hands between the origin and destination of the lift. The distance multiplier can be determined by the following data found in Table 24.4.

TABLE 24.3

Vertical Multiplier

Metric System		US System	
V (cm)	**VM**	**V (in.)**	**VM**
0	0.78	0	0.78
10	0.81	5	0.81
20	0.84	10	0.85
30	0.87	15	0.89
40	0.90	20	0.93
50	0.93	25	0.96
60	0.96	30	1.00
70	0.99	35	0.96
80	0.99	40	0.93
90	0.96	45	0.89
100	0.93	50	0.85
110	0.90	55	0.81
110	0.87	60	0.78
120	0.84	65	0.74
130	0.81	70	0.70
140	0.78	>70	0.00
150	0.75		
160	0.75		
170	0.72		
175	0.70		
>175	0.00		

Source: Developed from DHHS (NIOSH) Publication No. 94–110.

TABLE 24.4

Distance Multiplier

Metric System		US System	
D (cm)	**DM**	**D (in.)**	**DM**
≤25	1.00	≤10	1.00
40	0.93	15	0.94
55	0.90	20	0.91
70	0.88	25	0.89
85	0.87	30	0.88
100	0.87	35	0.87
115	0.86	40	0.87
130	0.86	45	0.86
145	0.85	50	0.86
160	0.85	55	0.85
175	0.85	60	0.85
>175	0.00	70	0.85
		>70	0.00

Source: Developed from DHHS (NIOSH) Publication No. 94-110.

Asymmetry Component[2]

Asymmetry refers to a lift that begins or ends outside the midsagittal plane, as shown in Figure 24.1. Asymmetric lifting should be avoided whenever possible. If asymmetric lifting cannot be avoided, however, the RWLs are significantly less than those limits used for symmetrical lifting.

Table 24.5 shows the asymmetric multipliers for various angles. The asymmetric multipliers apply to both the metric and US systems.

Frequency Component[2]

The frequency multiplier is defined by (a) the number of lifts per minute (frequency), (b) the amount of time engaged in the lifting activity (duration), and (c) the vertical height of the lift from the floor. Lifting frequency (F) refers to the average number of lifts made per minute, as measured over a 15-min period.

Lifting Duration

Lifting duration is classified into three categories: short, moderate, and long duration. *Short duration* pertains to lifting tasks that have a work duration of 1 h or less, followed by a recovery time equal to 1.2 times the work time. *Moderate duration* concerns lifting tasks that have a duration of more than 1 h, but less than 2 h, followed by a recovery period of at least 0.3 times the work time. *Long duration* pertains to lifting tasks that have a duration of between 2 and 8 h, with standard industrial rest allowances.

TABLE 24.5

Five Asymmetry Multipliers

A (Angle-Degree)	AM
0	1.00
15	0.95
30	0.90
45	0.86
60	0.81
75	0.76
90	0.71
105	0.66
120	0.62
135	0.57
>135	0.00

Source: Developed from DHHS (NIOSH) Publication No. 94-110.

Frequency Multiplier

See Table 24.6.

Coupling Component[2]

The nature of the hand-to-object coupling or gripping method can affect not only the maximum force a worker can or must exert on the object, but also the vertical location of the hands during the lift. A *good* coupling will reduce the maximum grasp forces required and increase the acceptable weight for lifting, while a *poor* coupling will generally require higher maximum grasp forces and decrease the acceptable weight for lifting.

There are three hand-to-object classifications: good, fair, and poor. *Good* is defined as handles or hand-hold cutouts of optimal design or a comfortable grip in which the hand can be easily wrapped around the object. *Fair* can be defined as handles or hand-hold cutouts of less than optimal design or a grip in which the hand can be flexed approximately 90°. *Poor* can be defined

TABLE 24.6

Frequency Multiplier

Frequency, Lifts/min (F)[a]	Work Duration					
	≤1 h		>1 h but ≤ 2 h		>2 h but <8 h	
	$V < 30$[b]	$V \geq 30$	$V < 30$	$V \geq 30$	$V < 30$	$V \geq 30$
≤ 0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

Source: Developed from DHHS (NIOSH) Publication No. 94-110.

[a]*For lifting less frequently than once per 5 min, set F = 0.2.*

[b]*Values of V are in inches.*

TABLE 24.7
Coupling Multiplier

	Coupling Multiplier	
Coupling Type	**V < 30 in. or 75 cm**	**V ≥30 in. or 75 cm**
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

as containers with less than optimal design or loose parts that are hard to handle or nonrigid bags that may sag in the middle.

Coupling Multiplier

See Table 24.7.

Lifting Index[2]

As mentioned previously in the Definitions section, the lifting index is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship between the weight of the load lifted and the RWL. To calculate the lifting index, we use the following equation:[3]

$$\text{Lifting Index}(\text{LI}) = \frac{\text{Object Weight}(L)}{\text{RWL}}.$$

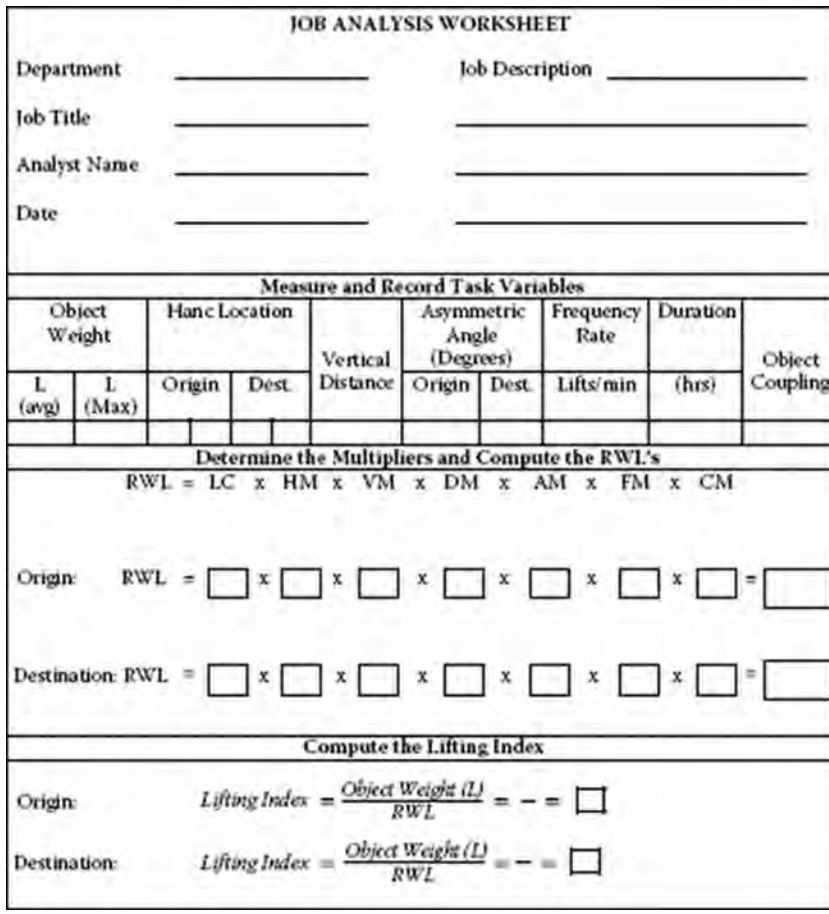
Ergonomic Job Analysis Worksheet

Figure 24.2 is a useful tool in determining the recommended weight limits at both the origin and destination points of a lift. Figure 24.3 provides an explanation of the various parts of the Job Analysis Worksheet.

Example Problems

Problem 1

A typical operation involves a punch press operator routinely handling small parts, feeding them into a press, and removing them. Occasionally (once per



JOB ANALYSIS WORKSHEET

Department _____ Job Description _____

Job Title _____ _____

Analyst Name _____ _____

Date _____ _____

Measure and Record Task Variables

Object Weight		Hand Location		Vertical Distance	Asymmetric Angle (Degrees)		Frequency Rate	Duration	Object Coupling
L (avg)	L (Max)	Origin	Dest.		Origin	Dest.	Lifts/min	(hrs)	

Determine the Multipliers and Compute the RWL's

RWL = LC x HM x VM x DM x AM x FM x CM

Origin: RWL = ☐ x ☐ x ☐ x ☐ x ☐ x ☐ x ☐ = ☐

Destination: RWL = ☐ x ☐ x ☐ x ☐ x ☐ x ☐ x ☐ = ☐

Compute the Lifting Index

Origin: $Lifting\ Index = \frac{Object\ Weight\ (L)}{RWL} = _ = \square$

Destination: $Lifting\ Index = \frac{Object\ Weight\ (L)}{RWL} = _ = \square$

FIGURE 24.2
Job analysis worksheet.

shift), the operator must load a heavy reel of supply stock from the floor onto the machine. The diameter of the reel is 30 in., the width of the reel between the worker's hands is 12 in., and the reel weighs 44 lb. Significant control of the load is required at the destination of the lift owing to the design of the machine (see Figure 24.4).

Determine the RWL and the lifting index using the revised NIOSH lifting equation. The multipliers can be determined from the tables shown previously (Figure 24.5). By evaluating this process, we have determined the following:

- At its origin, the object is 2.7 times the RWL.
- At its destination, the object is 3 times the RWL.

EXPLANATION OF THE ERGONOMICS JOB ANALYSIS WORKSHEET

JOB ANALYSIS WORKSHEET			
Department:	Shipping	**Job Description:** Loading paper supply rolls	
Job Title:	Packager		
Analyst Name:	Sharon Spear	**Date:** XX/XX/XXXX	

Measure and Record Task Variables											
Object Weight		Hand Location				Vertical Distance	Asymmetric Angle (Degrees)		Frequency Rate (lifts/min)	Duration (hrs)	Object Coupling
L (Avg)	L (Max)	Origin		Dest.			Origin	Dest.			
35	35	15	27	20	10	17	0	0	<0.2	<1	Poor

Average weight of object (this is the one used in the equation

Horizontal hand location (in inches) from the lifter (outward)

Vertical hand location (in inches) from the floor

Vertical distance between origin and destination (in inches)

Angle from the sagittal plane

FIGURE 24.3
Job analysis worksheet component explanation (Source: Yates, W. David 2019).

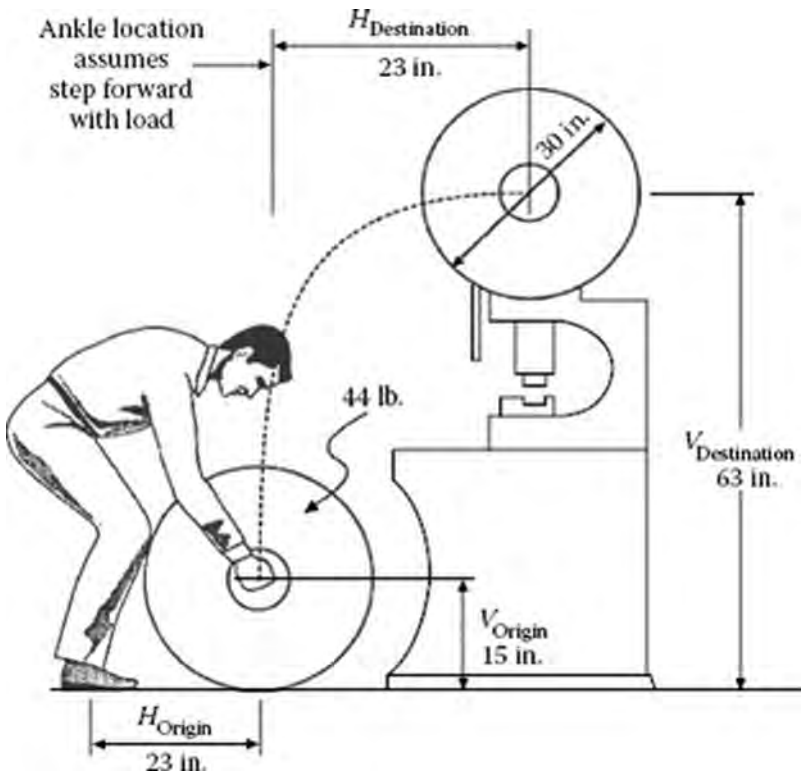


FIGURE 24.4
Loading punch press stock (Source: From DHHS (NIOSH) Publication No. 94-110).

Example 1 JOB ANALYSIS WORKSHEET

Department: Operations — Job Description: Loading supply stock

Job Title: Punch Press Operator — onto punch press machine

Analyst Name: Bob Jones

Date: XX/XX/XXXX

Measure and Record Task Variables

Object Weight		Hanc Location				Vertical	Asymmetric Angle (Degrees)		Frequency Rate	Duratior	Object
L (avg)	L (Max)	Origin		Dest.		Distance	Origin	Dest.	Lifts/min	(hrs)	Coupling
44	44	23	15	23	63	48	0	0	<0.2	<1	Fair

Determine the Multipliers and Compute the RWL's

RWL = LC x HM x VM x DM x AM x FM x CM

Origin: RWL	=	51	x	.44	x	.89	x	.86	x	1.0	x	1.0	x	.95	=	16.3 lbs
Destination: RWL	=	51	x	.44	x	.75	x	.86	x	1.0	x	1.0	x	1.0	=	14.5 lbs

Compute the Lifting Index

Origin: $\text{Lifting Index} = \frac{\text{Object Weight (L)}}{\text{RWL}} = \frac{44}{16.3} = \boxed{2.7}$

Destination: $\text{Lifting Index} = \frac{\text{Object Weight (L)}}{\text{RWL}} = \frac{44}{14.5} = \boxed{3.0}$

FIGURE 24.5
Example 1. Job analysis worksheet.

The question now is, "What can be done to prevent injuries arising from this process?"

These lifting indices indicate that the lift would be hazardous for a majority of healthy industrial employees. There are numerous possibilities for reducing or eliminating potential injuries in this process. A few of them are listed as follows:

- Engineer the lifting out of the operation, if possible.
- Bring the object closer to the worker at the destination to increase the HM value.
- Lower the destination of the lift to increase the VM value.

- Reduce the vertical distance between the origin and the destination of the lift to increase the DM value.
- Modify the job so that significant control of the object at the destination is not required. This will eliminate the need to use the lower RWL value at the destination.

Problem 2

An employee is assigned to load bags into a hopper. The employee positions himself midway between the hand truck and the mixing hopper (see Figure 24.6). Without moving his feet, he twists to the right and picks up a bag off the hand truck. In one continuous motion, he then twists to his left to place the bag on the rim of the hopper. A sharp-edged blade within the hopper cuts open the bag to allow the contents to fall into the hopper. This task is done infrequently (1–12 times per shift) with large recovery periods between lifts (>1.2 h recovery time). In observing the worker perform the job, it was determined that the non-lifting activities could be disregarded because they require minimal force and energy. Significant control is not required at the destination, but the worker twists at the origin and destination of the lift. Although several bags are stacked on the hand truck, the highest risk of overexertion injury is associated with the bottom bag (Figure 24.6).

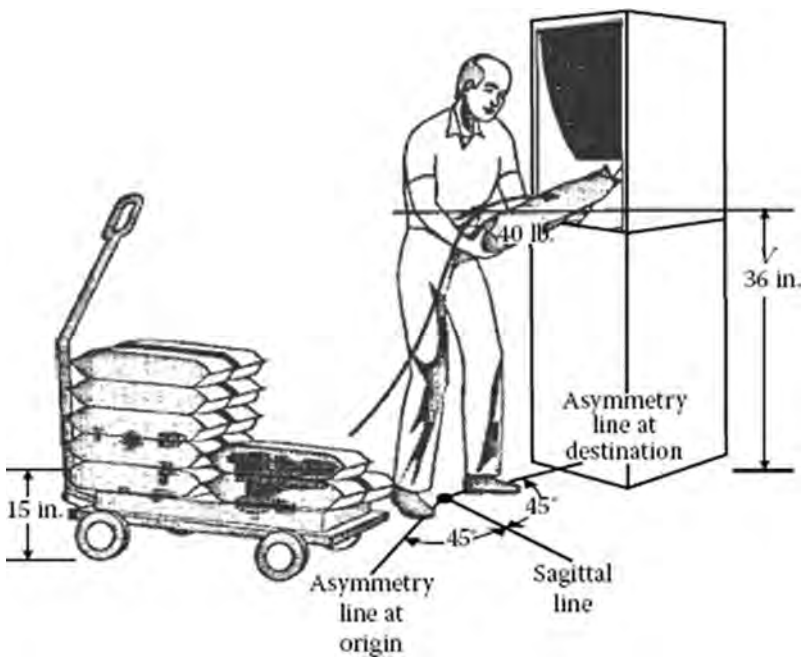


FIGURE 24.6
Loading bags into a hopper (Source: From DHHS (NIOSH) Publication No. 94-110).

By evaluating this process, we have determined the following:

- At its origin, the object is 2.1 times the RWL.
- This lift would be physically stressful for most industrial workers.

Some redesign suggestions to improve this process and potentially prevent employee injuries are as follows:

- Bringing the load closer to the worker increases the HM.
- Reducing the angle of asymmetry to increase the AM could be accomplished by moving the origin and destination points closer together or further apart.
- Raising the height at the origin to increase VM.

Hopper Example JOB ANALYSIS WORKSHEET

Department: Operations — Job Description: Loading supply stock

Job Title: Punch Press Operator — onto punch press machine

Analyst Name: Bob Jones

Date: XX/XX/XXXX

Measure and Record Task Variables

Object Weight		Hanc Location				Vertical Distance	Asymmetric Angle (Degrees)		Frequency Rate	Duration	Object Coupling
L (avg)	L (Max)	Origin		Dest.			Origin	Dest.	Lifts/min	(hrs)	
40	40	18	15	10	36	21	45	45	<0.2	<1	Fair

Determine the Multipliers and Compute the RWL's

RWL = LC x HM x VM x DM x AM x FM x CM

Origin: RWL = 51 x .56 x .89 x .91 x .86 x 1.0 x .95 = 18.9 lbs

Destination: RWL = ☐ x ☐ x ☐ x ☐ x ☐ x ☐ x ☐ = ☐

Compute the Lifting Index

Origin: $\text{Lifting Index} = \frac{\text{Object Weight (L)}}{\text{RWL}} = \frac{40}{18.9} = \boxed{2.1}$

Destination: $\text{Lifting Index} = \frac{\text{Object Weight (L)}}{\text{RWL}} = - = \square$

FIGURE 24.7
Hopper example. Job analysis worksheet.

Rapid Upper Limb Assessment (RULA)

The Rapid Upper Limb Assessment (RULA) is an ergonomic tool that was developed to rapidly evaluate an employee's ergonomic risk factors associated with upper extremity musculoskeletal disorders (MSDs). There are various commercial charts on the market that show a simple RULA process that can be utilized by those who don't have advanced degrees or an understanding of ergonomics. However, most professionals utilize available software such as VelocityEHS Ergonomics, ErgoPlus, and TuMeke. This author's experience is primarily based on TuMeke software but that is not to specifically endorse this software over the others mentioned or not mentioned. By using these software packages, the evaluator simply takes a short video of the operation and uploads it to the software, then selects the appropriate evaluation, such as RULA.

Figure 24.8 is an example of a screenshot from a video taken and uploaded into the software package. Figures 24.9 and 24.10 show the RULA analysis that was performed on the operation.

Looking at the screenshots in Figures 24.8–24.10, the MSD risk was identified as a medium risk with the primary risks being in the upper arm, neck, and lower arm areas. Once this is determined, the evaluator can look to implement control measures, such as shortening or lowering the reach for assembly parts.



FIGURE 24.8
Screenshot from a video (RULA) (Source: Yates, W. David 2024).

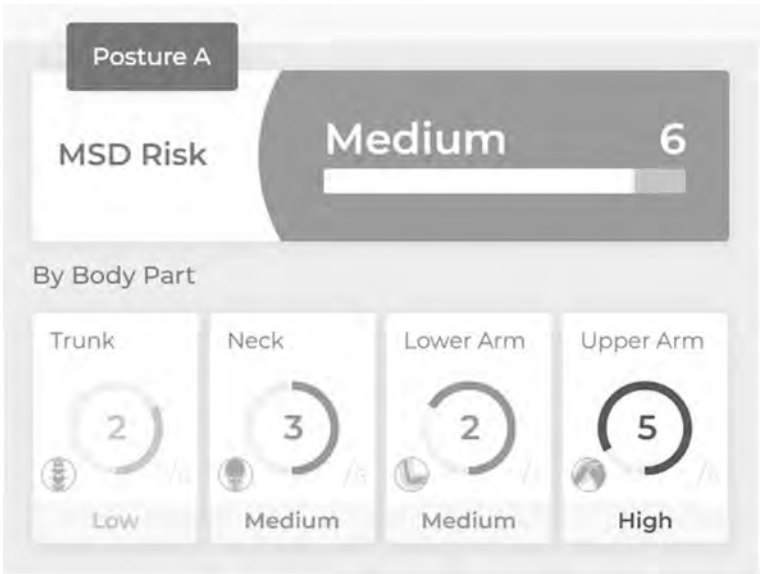


FIGURE 24.9
Screenshot posture analysis (RULA) (Source: Yates, W. David 2024).

Rapid Entire Body Assessment (REBA)

The Rapid Entire Body Assessment (REBA), like RULA, was developed to evaluate the risk of Musculoskeletal Disorders associated with certain tasks. Also like RULA, there are commercially available charts that will graphically represent the various steps in the REBA process. The commercially available software programs mentioned previously will also conduct REBA analysis on uploaded videos.

Figure 24.11 is a screenshot of a video taken and analyzed using the REBA tool in the software. Figures 24.12 and 24.13 graphically represent the REBA analysis results.

From the video and the screenshot of the operation and based on the analysis, it is determined that the primary risk comes in the upper arms. As you can see in the video screenshot, the upper arms and shoulders are raised too high. Therefore, one solution was to modify the workstation to allow for lower shoulder and arm movement.

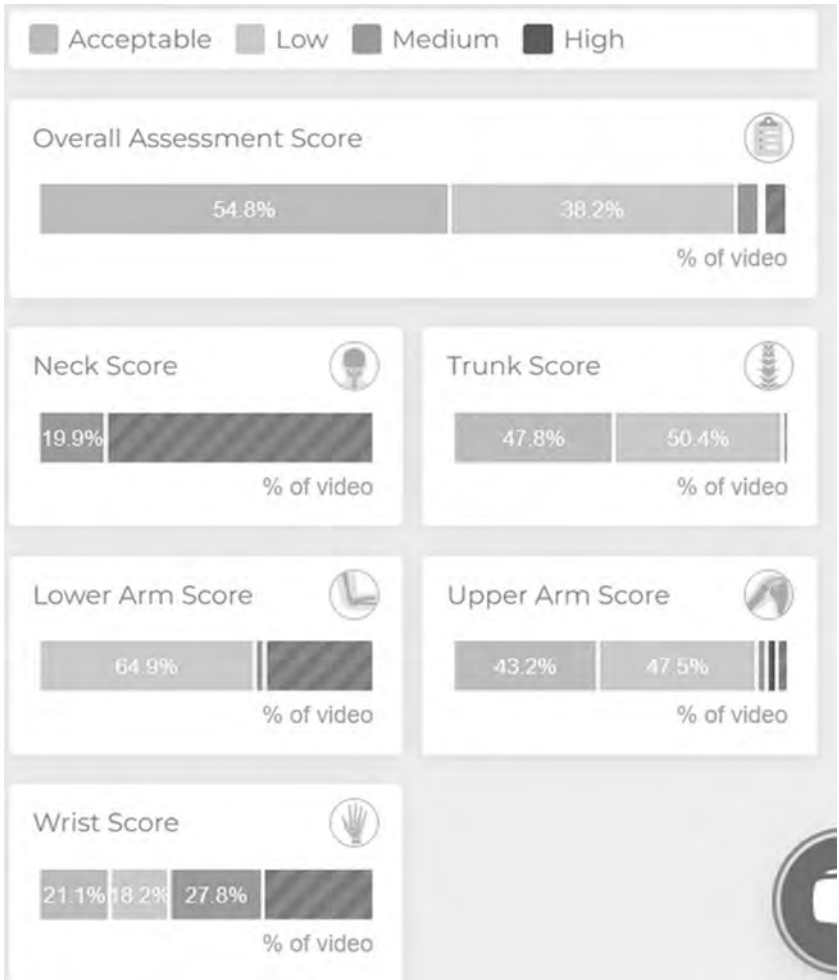


FIGURE 24.10
Screenshot for detailed RULA analysis (Source: Yates, W. David 2024).

Ergonomic Resources

While there are several commercially available ergonomic tools, there are also tools available at no cost. Some of those tools are available at https://libertymmhtables.libertymutual.com/, which provides various calculators for manual materials handling, including lifting, lowering, pushing, pulling, and carrying.



FIGURE 24.11
Screenshot of video for REBA analysis (Source: Yates, W. David 2024).

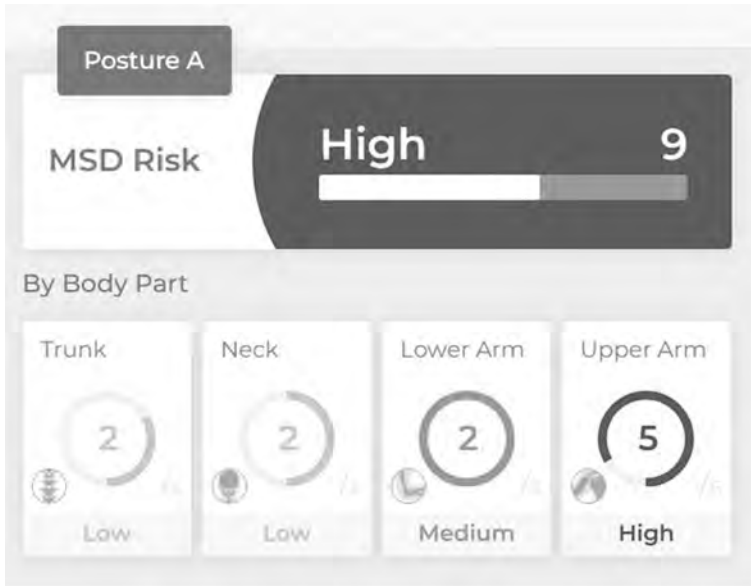


FIGURE 24.12
Screenshot for REBA posture analysis (Source: Yates, W. David 2024).

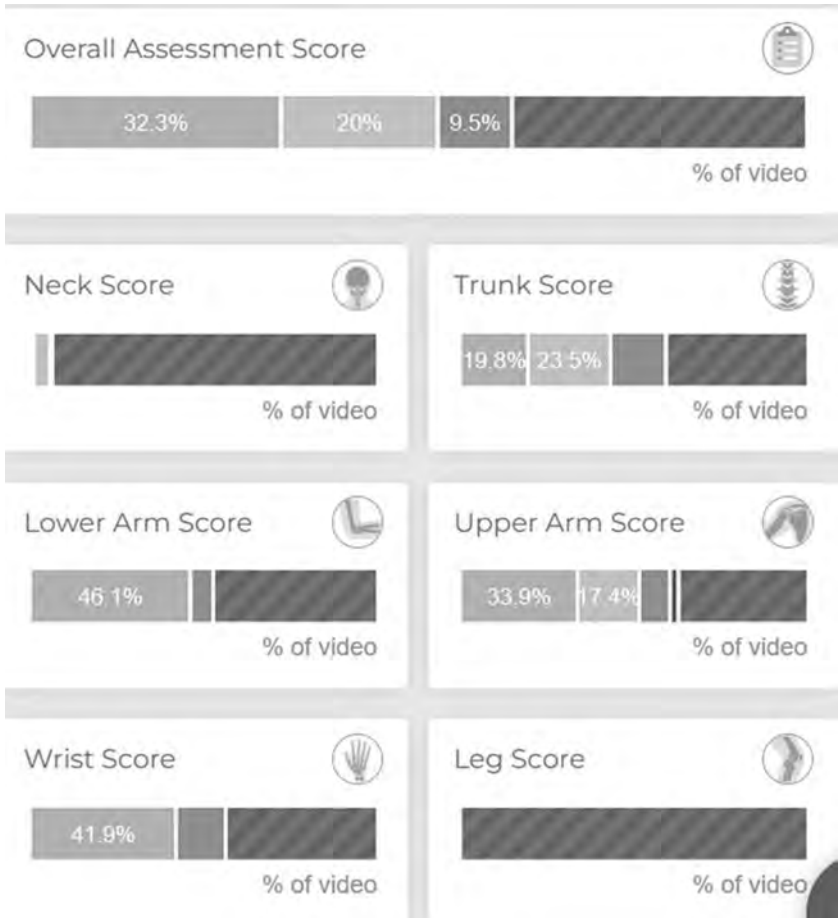


FIGURE 24.13
Detailed posture analysis (REBA) (Source: Yates, W. David 2024).

Key Information to Remember on Ergonomics

1. The recommended weight limit (RWL) is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers can perform over a substantial period (up to 8 h) without an increased risk of developing lifting-related low back pain or injury.
2. The lifting index is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. It is a ratio between the weight of the object and the RWL.

3. Horizontal location is the distance of the hands away from the midpoint between the ankles (measured in inches or centimeters).
4. The vertical location is the distance of the hands above the floor.
5. The vertical travel distance is the absolute value of the difference between the vertical heights at the destination and the origin of the lift.
6. Asymmetry angle is the angular measure of how far the object is displaced from the front (midsagittal plane) of the worker's body at the beginning or ending of a lift (measured in degrees).
7. Lifting frequency is the average number of lifts in a 15-min period.
8. Lifting duration is classified as short, moderate, or long duration.
9. Coupling classifications are good, fair, or poor.
10. Significant control is defined as a condition requiring precise placement of the load at the destination of the lift.

References

1. Karwowski, W. and Marras, W. S. 1999. *Occupational Ergonomics Handbook*, CRC Press, Boca Raton, FL, p. 4.
2. U.S. Department of Health and Human Services. 1994. NIOSH Revised Lifting Equation. National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH.

25

Construction Safety

Table 25.1 shows the 2022 statistics for fatal construction industries by cause. Construction fatalities account for nearly 20% of all work-related fatalities.[1]

The following were the top 10 most frequently cited standards by Federal OSHA in fiscal year 2022 (October 1, 2021, through September 30, 2022):[2]

1. Fall protection, construction (29 CFR 1926.501)
2. Hazard communication standard, general industry (29 CFR 1910.1200)
3. Respiratory protection, general industry (29 CFR 1910.134)
4. Ladders, construction (29 CFR 1926.1053)
5. Scaffolding, general requirements, construction (29 CFR 1926.451
6. Control of hazardous energy (lockout/tagout), general industry (29 CFR 1910.147)
7. Powered industrial trucks, general industry (29 CFR 1910.178)
8. Fall Protection–Training Requirements (29 CFR 1926.503)
9. Eye and Face Protection (29 CFR 1926.102)
10. Machinery and Machine Guarding, general requirements

Excavation

An excavation is defined as any man-made cut, cavity, trench, or depression in the earth's surface. A trench is considered an excavation. Employees working on or near construction sites must be protected from cave-ins when the excavation is 4 ft or more in depth. Cave-in protection is not required when (a) excavations are made entirely of stable rock or (b) they are less than 4 ft in depth, and examination of the ground by a competent person provides no indication of a potential cave-in.

The hazards associated with an excavation are numerous and include weight (nearby vehicles/equipment), vibration, underground utilities, water, and soil erosion. The "competent person" must take all of these factors into consideration when evaluating an excavation. In addition, the hazards and conditions at an excavation site change frequently and should be continuously reevaluated.

DOI: 10.1201/9781003511786-25

TABLE 25.1

Bureau of Labor and Statistics Construction Fatalities for 2022[1]

Event	No. of Fatalities	Percentage of Construction Fatalities (%)
Total fatalities	1069	100
Contact with objects and equipment	149	14
Falls	410	38
Exposure to harmful substances	194	18
Transportation incidents	243	23
Other causes	73	7

The spoils pile (materials removed from the excavation) and the equipment being too close to the vertical walls of the trench are called "surcharge loads," which increase the likelihood of collapse. Additionally, equipment vibration, adverse weather conditions, and groundwater can change the condition and classification of soil.

A competent person is someone who:

- Can identify existing or predictable hazards in excavations.
- Has the authority to take corrective actions as necessary.
- Is familiar with the OSHA regulations and standards for excavations.
- Is knowledgeable in soil analysis and classification, as well as the erection, use, and precautions for the protective system on site.

A Registered Professional Engineer (RPE) is a person registered as an engineer in the state where the excavation is being performed.

The procedures for safe trench work include the following:

- Identify the knowledgeable, competent person.
- Check and verify above-ground and below-ground utility locations, any adjacent structures or surface encumbrances, and the water table.
- Determine the soil classification through testing.
- Verify protective system installation and setup.
- Provide safe access.
- Comply with requirements specified in the "Excavation, Trenching, and Shoring" regulations.
- Conduct daily inspections prior to the start of work, after any weather event, and as needed.

Note: Each city, state, or municipality has a toll-free number to call regarding the location of underground utilities.

Soil Classifications

It is crucial to correctly classify soil types before selecting and using a protective system. Soil types are classified as Type A, B, or C. To classify soil, at least one visual test and one manual test are required. If soil is classified as Type C, then no testing is required. Table 25.2 shows the characteristics of each soil type.

Protective Systems

The choices of protective systems include sloping and benching, shoring, and shield systems. Protective systems are required under the following conditions:

- Under 4 ft deep when there is a potential for cave-ins.
- Four to 20 ft deep.

TABLE 25.2

Soil Classification Characteristics (29 CFR 1926 Subpart P)

Soil Type	Soil Characteristics
A	Good cohesive soil with a high compressive strength includes clay, silty clay, sandy clay, clay loam, and cemented soils such as caliche, duricrust, and hardpan. • Fine grained • Does not crumble • Hard to break up when dry
B	Cohesive soil with a moderate compressive strength such as silt, silty clay, sandy clay, sandy loam, angular gravel (similar to crushed rock), or any previously disturbed fissure or soil subject to vibration. • Granular-coarse grains • Little or no clay content • Crumbles easily when dry
C	Cohesive soil with a low compressive strength, such as granular soils including gravel, sand, and loamy sand, or submerged soil or rock that is not stable, or soil from which water is freely seeping. • Granular soil—very coarse • Minimal cohesion

- Sloping or benching (benching is not an option in Type C soils).
- Shield or shoring systems.
- Over 20 ft deep—protective systems must be designed by an RPE or approved in the manufacturer's tabulated data.

Note: Protective system is not required for stable rock.

Sloping

Sloping is the process of removing soil to eliminate the chance of a cave-in. The required maximum allowable slope is determined by the soil classification. The maximum allowable slope for each soil type is listed in Table 25.3.

An example of sloping in Type C soil is shown in Figure 25.1.

TABLE 25.3

Maximum Allowable Slope (29 CFR 1926 Subpart P)

Soil Type	H:V Ratio	Angle (°)
Stable rock	Vertical	90
A	3/4:1	53
B	1:1	45
C	11/2:1	34

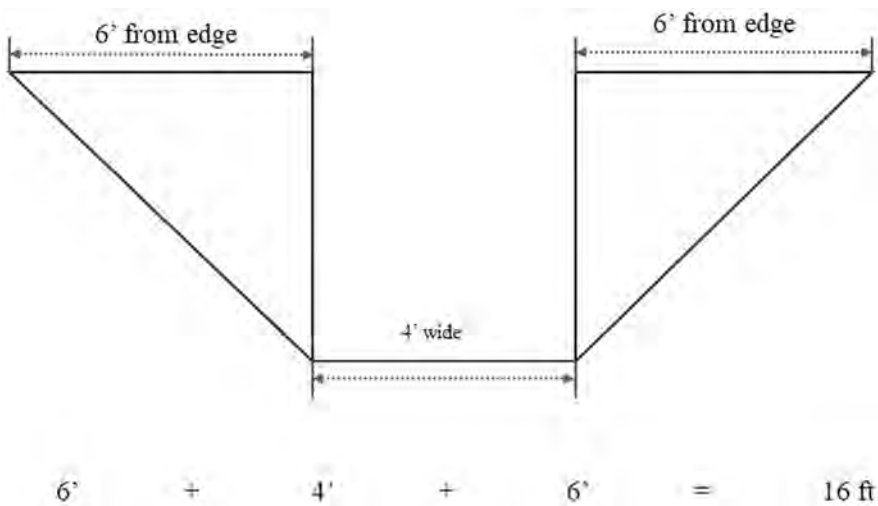


FIGURE 25.1
Example of slope required for Type C soil (Source: 29 CFR 1926 Subpart P).

Shoring

Shoring is one of the most used methods of worker protection in excavations. It is lightweight and easy to install. The manufacturer provides tabulated data with the shoring that details the limitations, precautions, required spacing, and proper use.

Shields (Trench Boxes)

Shields are manufactured by several companies and are designed to protect workers working within the confines of the shields. Check the tabulated data for the maximum allowable depth at which it can be used. The tabulated data must accompany the shield when it is being used. Additionally, the shield must be designed by an RPE, be in good condition, and be used properly.

When shields that don't go all the way to the bottom of the trench are used, the excavation should be no deeper than 2 ft from the bottom of the shield. Furthermore, the system must be designed to resist forces calculated for the full depth of the trench, and there should be no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.

RPE-Designed Protective Systems

An RPE can design a protective system for use on a specific project. The RPE should consider the soil type and conditions, as well as other concerns that might exist at the excavation site. The system must be designed by the RPE. The competent person must still perform daily inspections to verify site conditions and any changes that have occurred.

Safe Entry and Exit

A trench that is 4 ft or more in depth must have a safe means for workers to get in and out of the trench. A means of egress is required to be within 25 ft of lateral travel. The most common method for access is a straight ladder or an extension ladder. If a ladder is used, it must extend a minimum of 3 ft above the landing. The use of step ladders is not permitted. Other means of access could be a stairway, ramp, or other methods as designed by an RPE. Locating the method of access/egress outside the protective system is strictly prohibited. Buckets of excavators, backhoes, and so on are not to be used as a means of egress.

Most Cited Trenching Violations

Some of the most cited trenching violations include the following:

- No cave-in protective system being used when required by soil classification, depth, or code
- Excessive surcharge load (spoils pile too close to the excavation wall or equipment traffic too close to excavation operations)
- No access/egress for excavations 4 ft or more in depth
- No competent person on site

Electrical Safety in Construction

Approximately five workers in construction are electrocuted each week. Electricity causes 12% of young worker work-related deaths each year. It takes very little electricity to cause harm. Electricity as low as 50 mA can cause death. In addition, where electricity is present, there is a significant risk of causing fires.[3]

Electricity is the flow of energy from one location to another. It requires a source of energy, usually a generating station. The flow of electrons (current) travels through a conductor and then travels in a closed circuit.

Electrical Definitions

The following definitions are provided for your use throughout this chapter:

Current: Electrical movement (measured in amperes)

Circuit: Complete path of the current; includes an electricity source, a conductor, and the output device or load (such as a lamp, tool, or heater)

Resistance: Restriction to electrical flow

Conductor: Substances, such as metals, with little resistance to electricity that allow electricity to flow.

Grounding: A conductive connection to the earth that acts as a protective measure

Insulator: Substances with high resistance to electricity (like glass, porcelain, plastic, and dry wood) that prevent electricity from reaching unwanted places

Electrical Injuries

There are four main types of electrical injuries, categorized as either direct or indirect injuries. Each of these is listed below:

- Direct
- Electrocution or death because of electric shock
- Electrical shock
- Burns
- Indirect
- Falls

Electrical Shock

An electrical shock is received when electrical current passes through the body. A person will get an electrical shock if a part of his or her body completes an electrical circuit by either touching a live wire and an electrical ground or touching a live wire and another wire at a different voltage. The severity of the shock depends on (a) the path of the current through the body, (b) the amount of current flowing through the body (amperes), and (c) the duration of the shocking current through the body.

Note: Low voltage does not mean low hazard.

Currents above 10 mA can paralyze or freeze the muscles. Currents above 75 mA can cause a rapid, ineffective heartbeat, and death will occur in a few minutes unless a defibrillator is used. Electrical current as low as 75 mA can cause death. A milliampere (mA) is equal to 1/1000 A.

Burns

Burns are the most common shock-related injury. Burns occur when you touch electrical wiring or equipment that is improperly used or maintained. They typically occur on the hands. Burns are very serious injuries that require immediate medical attention.

Falls

Electric shock can also cause indirect injuries. Workers in elevated locations who experience a shock may fall, resulting in serious injury or death.

Controlling Electrical Hazards

Electrical accidents are caused by a combination of three factors:

- Unsafe equipment or installations
- Workplaces made unsafe by the environment
- Unsafe work practices

Exposed Electrical Parts

Exposed electrical parts present the most common type of hazard on a construction site. To prevent injuries from exposed electrical parts, you must isolate the parts by the use of guards or barriers and replace missing covers. Conductors going into electrical cabinets, boxes, or fittings must be protected and unused openings must be closed. Junction boxes, pull boxes, and fittings must have approved covers. Unused openings in cabinets, boxes, and fittings must be closed. There must be no missing knockouts.

Overhead Power Lines

Overhead power lines are not usually insulated. Some examples of equipment that come into contact with power lines include cranes, ladders, scaffolding, backhoes, scissor lifts, raised dump truck beds, and aluminum paint rollers. To control the hazards presented by overhead power lines:

- A worker should stay at least 10 ft away.
- A worker can post warning signs.
- A worker should assume that lines are energized.
- A worker should use wood or fiberglass ladders, not metal.
- Power line workers need special training and personal protective equipment.

Inadequate Wiring

Inadequate wiring exists whenever the wiring is too small for the amount of current. For example, a portable tool used with an extension cord that has a wire too small for the tool presents a significant hazard. The tool will draw more current than the cord can handle, causing overheating and a possible fire without tripping the circuit breaker. The circuit breaker could be the right size for the circuit but not for the smaller extension cord. To control the hazard of inadequate wiring, use the correct-sized wire. The wire used depends on operation, building materials, electrical load, and environmental

factors. Use fixed cords rather than flexible cords and use the correct extension cord, which must be 3-wire type and designed for hard or extra-hard use.

Defective or Damaged Cords and Wires

All too often on construction sites, cords become damaged through aging, door or window edges, staples or fastenings, abrasion from adjacent materials, or activity in the area. Improper use of these cords can cause shocks, burns, or fires. To control the hazards associated with damaged or defective cords or wires, use one or more of the following control methods:

- Insulate live wires
- Inspect all cords and wires before each use
- Use only cords that are of the 3-wire type
- Use only cords marked for hard or extra-hard usage.
- Use only cords, connection devices, and fittings equipped with strain relief.
- Remove cords by pulling on the plugs, not the cord.
- Cords not marked for hard or extra-hard use, or which have been modified or damaged, must be taken out of service immediately.

Use of Flexible Cords

Do not use flexible wiring where frequent inspection would be difficult or where damage would likely occur. Flexible cords must not be

- Run through holes in walls, ceilings, or floors
- Run through doorways, windows, or similar openings unless physically protected
- Hidden in walls, ceilings, floors, conduits, or other raceways

Grounding

Grounding creates a low-resistance path from a tool to the earth to disperse unwanted current. When a short or lightning occurs, energy flows to the ground, protecting you from electrical shock or death. Tools plugged into improperly grounded circuits may become energized. Broken wires or plugs on an extension cord can create an improper grounding situation. Improper grounding is one of the most frequently cited violations of the OSHA standard (Table 25.4).

To properly control improper grounding, use one or more of the following control methods:

TABLE 25.4

Minimum Specification for Bonding and Grounding (29 CFR 1910.305)

Bonding wires	4.1 mm (#6 AWG) copper wire
Bonding connectors	12.7 mm (1/2″) copper bonding straps, solder lugs, pressure connectors, or bolts and star washer
Bonding conductors	19 mm (3/4″) copper braid with pressure-type clamps
Grounding wires	5.2 mm (#4 AWG) copper wire
Grounding connectors	At the equipment: Approved connectors securely bolted to the machine. Solder lugs are acceptable, but pressure connectors are preferable At the earth: An approved ground clamp attached to a ground electrode

- Ground power supply systems, electrical circuits, and electrical equipment.
- Frequently inspect electrical systems to ensure the path to ground is continuous.
- Inspect electrical equipment before each use.
- Do not remove ground prongs from tools or extension cords.
- Ground exposed metal parts of equipment.

Ground Fault Circuit Interrupters

Ground fault circuit interrupters (GFCIs) protect from electrical shock by detecting the difference in current between the black and white wires. If a ground fault is detected, the GFCI shuts off electricity in 1/40th of a second. Use GFCIs on all 120-V, single-phase, 15-, and 20-A receptacles or have an assured equipment grounding conductor program.

Assured Equipment Grounding Conductor Program

An Assured Equipment Grounding Conductor Program must cover

- All cord sets
- Receptacles not part of a building or structure
- Equipment connected by plug and cord

The program requirements include the following:

- Specific procedures adopted by the employer
- Competent person to implement the program
- Visual inspection for damage of equipment connected by cord and plug

Overloaded Circuits

Another frequent occurrence on construction sites is overloaded circuits. The hazards from overloaded circuits can result from too many devices plugged into a circuit, causing heated wires and possibly fires. Hazards can also result from damaged tools overheating, lack of overcurrent protection, and wire insulation melting, which may cause arcing and a fire in the area where the overload exists, even inside a wall. Overloaded circuit hazards can be controlled through the use of electrical protective devices that automatically open the circuit if excess current from overload or ground fault is detected, shutting off the electricity. Electrical protective devices include GFCIs, fuses, and circuit breakers. Fuses and circuit breakers are overcurrent devices. When too much current is present, the fuses melt and the circuit breakers trip open (opening the circuit, which prevents the flow of current).

Safety-Related Work Practices

To protect workers from electrical shock, the following work practices should always be enforced:

- Use barriers and guards to prevent passage through areas of exposed, energized equipment.
- Preplan work and post hazard warnings.
- Keep working spaces and walkways clear of cords.
- Use special insulated tools when working on fuses with energized terminals.
- Do not use worn or frayed cords and cables.
- Do not fasten extension cords with staples, hang them from nails, or suspend them by wire.

Planning

One of the first steps in preventing electrical injuries and accidents is to plan your work. Let others that you are working with or around know about your proposed activities. Plan to avoid falls that may result from your work. When working around electrical equipment, strictly follow the lockout/tagout program. Ensure that you or others working around electricity remove all jewelry and avoid wet conditions and overhead power lines.

Training

All employees working with electric equipment should be trained in safe work practices, which include the following:

TABLE 25.5

Electrical Hazards and Control Measures

Hazard	Control Measures
• Inadequate wiring	• Proper grounding
• Exposed electrical parts	• Use GFCIs
• Ungrounded electrical systems and tools	• Use fuses and circuit breakers
• Overloaded circuits	• Guard live parts
• Damaged power tools and equipment	• Lockout/tagout
• Using the wrong PPE and tools	• Proper use of flexible cords
• Overhead power lines	• Close electric panels
• All hazards are made worse in wet conditions	• Training
	• Planning

- Deenergizing electric equipment prior to inspecting or repairing
- Using cords, cables, and electrical tools that are in good repair
- Lockout/tagout recognition and procedures
- Using appropriate personal protective equipment

Summary

The hazards and control measures associated with electricity are summarized in Table 25.5.

Static Electricity

One form of electricity can be a major problem on construction sites if not addressed. Static electricity should be addressed around fuel storage areas, other explosive environments (such as areas with high dust concentrations), and high-pressure vacuuming.

What is static electricity? At its simplest, static electricity is an electrical charge that cannot move. It is created when two objects or materials that have been in contact with each other are separated. When in contact, the charges try to balance each other (free flow of electrons—negatively charged particles). When separated, they are left with either an excess or a shortage of electrons. This causes both objects to become electrically charged. If these charges don't have a path to ground, they are unable to move and become "static." If static electricity is not rapidly eliminated, the charge will build up.

It will eventually develop enough energy to jump, in the form of a spark, to some nearby grounded or less highly charged object in an attempt to balance the charge.

- Liquid flows through a pipe or hose
- Spraying or coating
- Blending and mixing
- Filling drums, cans, or pails
- Dry powdered material passes through chutes or hoses
- Nonconductive conveyor belts or drive belts

The main hazard from static electricity is the creation of sparks in an explosive or flammable atmosphere. The danger is greatest when flammable liquids are being poured or transferred. Static electricity can also build up to the point where injury or even death can result from electrical shock.

There are four main conditions that must be present for static electricity to be a hazard. These conditions are listed as follows:

1. There must be a means for a static charge to develop.
2. Enough energy must build up to cause ignition.
3. There must be a discharge of this energy (a spark).
4. The spark must occur in an ignitable vapor or dust mixture.

Static electricity is controlled through (a) bonding and grounding, (b) humidification, (c) static controllers, or (d) additives. Each of these will be discussed individually.

Bonding and Grounding

Bonding and grounding are the most common methods of controlling static electricity. *Bonding* is connecting two or more conductive objects with a conductor, such as a copper wire, to equalize the potential charge between them. It should be noted that bonding does not eliminate the static charge. *Grounding* is connecting one or more conductive objects directly to the earth using ground rods, cold water pipes, or building steel. Unlike bonding, grounding drains the static charges away as quickly as they are produced.

Humidification

A high relative humidity is no guarantee against the accumulation of static electricity. Therefore, it should not be relied upon solely as a control measure in areas where there are flammable liquids, gases, or dust.

Static Controllers (Collectors)

Devices that collect static electricity can be used on moving belts, plastic film, and similar nonconductive materials. Examples of static collectors include needle-pointed copper combs, spring copper brushes, and metallic tinsel bars. To be effective, collectors must be properly grounded.

Additives

Antistatic additives (as in fuels) can be used to control static electricity. The additive increases the conductivity or lowers the resistance of the liquid. Additives also reduce the time it takes for the static charge to leak through the wall of the container and to the ground.

Scaffolds

No discussion on construction safety would be complete without discussing scaffolding. The standards and regulations on scaffolding discussed in this chapter can be found in 29 CFR 1926.450–454.[3] These requirements, however, do not apply to crane or derrick suspended platforms, which are covered by 29 CFR 1926.550.[4] Furthermore, the requirements for aerial lifts are in 29 CFR 1926.453.

A scaffold is an elevated, temporary work platform. There are three basic types of scaffolds, described in the following:

- *Supported scaffolds*: Platforms supported by rigid, load-bearing members, such as poles, legs, frames, and outriggers
- *Suspended scaffolds*: Platforms suspended by ropes or other nonrigid, overhead support
- *Aerial lifts*: Working platforms such as "cherry pickers" or "boom trucks"

Hazards associated with scaffolds include

- Falls from elevations are caused by slipping, unsafe access, and the lack of fall protection

- Being struck by falling tools or debris
- Scaffold collapse caused by instability or overloading
- Bad planking gives way

Fall Hazards

Falls may occur

- While climbing on or off the scaffold
- Working on unguarded scaffold platforms
- When scaffold platforms or planks fail

In general, workers on a scaffold who can potentially fall more than 10 ft must be protected by guardrails or personal fall arrest systems (PFASs). The specifics of fall prevention are discussed in the Fall Protection and Prevention in Construction section.

Falling Object (Struck by) Protection

Workers below a scaffold have too often been struck by objects such as tools or materials that fall from the scaffold. To mitigate the potential of falling objects striking workers below the scaffold, one or all of the methods listed below are recommended.

- All employees or visitors to the work site should be required to wear hard hats.
- The area beneath the scaffold should be barricaded to prohibit entry into the area.
- Use panels or screens if material is stacked higher than the toe board.
- Build a canopy or erect a net below the scaffold that will contain or deflect falling objects.

Elements of Safe Scaffold Construction

When scaffolding is required, it is to be designed and supervised by a *competent person*. The competent person shall ensure that appropriate scaffold construction methods are used, and the scaffold has proper access. A competent person is considered as one that can identify and promptly correct hazards. The competent person determines if it is safe to work on a scaffold during storms or high winds. In addition, the competent person selects qualified workers to conduct work on scaffolds and trains these workers to recognize hazards. The competent person is responsible for inspecting the scaffold for visible defects before each shift or after alterations. Defective parts must be immediately repaired prior to using the scaffold.

The platform of the scaffold must be fully planked or decked with no more than 1 in. gap. In addition, the platform must be at least 18 in. wide and capable of supporting its weight and four times the maximum load. The height of the scaffold should not be more than four times its minimum base dimension, unless guys, ties, or braces are used. Additional requirements of scaffold construction include the following:

- No large gaps at the front edge of the platform.
- Each abutted end of the plank must rest on a separate support surface.
- Overlap platforms at least 12 in. over supports, unless restrained to prevent movement.
- No paint on wooden platforms.
- Fully planked between the front upright and guardrail support.
- Component pieces used must match and be of the same type.
- Erect on stable and level ground.
- Lock wheels and braces.
- Each end of a platform, unless cleated or otherwise restrained by hooks, must extend 6 in. over its support.

Supported scaffold platforms. should be restrained from tipping by guys, ties, or braces. Scaffold poles, legs, posts, frames, and uprights must be on base plates and mud sills or other firm foundation. Scaffolds can only be erected, moved, dismantled, or altered under the supervision of a competent person. The competent person selects and directs trained workers and determines the feasibility of a fall.

Suspension scaffolds are platforms suspended by ropes or wires. The rope or wire must be capable of supporting six times the load. Employees must be trained to recognize hazards. The platform must be secured in order to prevent swaying. The support devices must rest on surfaces that can support four times the load. A competent person must evaluate connections to ensure that the supporting surfaces can support the loads and should inspect ropes and wires for defects before each shift. PFASs must have anchors that are independent of the scaffold support system.

Employees can't be on a moving scaffold unless

- Surface is level.
- Height-to-base ratio is 2:1.
- Outriggers are installed on both sides of the scaffold.
- A competent person is on site to supervise the movement.
- Employees are on the scaffolding portion inside the wheels.

Scaffold Training Requirements

All persons, including the competent person, scaffold erectors, and scaffold users, are to be trained on scaffold hazards and procedures to control the hazards. The training must include

- Nature of electrical, fall, and falling objects hazards
- How to deal with electrical hazards and fall protection systems
- Proper use of the scaffold
- Scaffold load capacities

Scaffold erectors and competent persons should receive additional training in erecting, disassembling, moving, operating, repairing, maintaining, and inspecting a scaffold.

Fall Protection and Prevention in Construction

As stated in the introduction to this chapter, falls account for approximately 40% of all construction-related fatalities. Therefore, it is incumbent upon the safety professional to have extensive knowledge of fall protection and prevention. The OSHA regulations covering fall protection are provided in 29 CFR 1926 (Subpart M)[4] (discussed in detail in Chapter 4). To further illustrate the significance of preventing falls, the following statistics are provided:

- Forty percent of the fatalities were from heights over 40 ft.
- Most falls occur on scaffolds or roofs.
- Twenty-five percent of fall fatalities were from heights of 11–20 ft.
- Twenty-five percent of fall fatalities were from heights of 20–30 ft.

Physics of a Fall

On average, it takes most people approximately 1/3 of a second to become aware. It takes another 1/3 of a second for the body to react to what is happening. Consider that the body can fall 7 ft in 2/3 (or 0.67) s or 64 ft in 2 s. By the time a person becomes aware and begins to react, they have already fallen 7 ft. Given these numbers and the likelihood of death or serious injury, one can determine that the potential for falls in the construction industry requires the attention of safety professionals. The anatomy of a fall is discussed in greater detail in Chapter 26.

Fall Prevention and Protection[5]

When discussing falls, it is incumbent upon the safety professional to understand the difference in fall prevention and protection philosophies. The two philosophies are *fall prevention* and *fall protection.* Fall prevention is the process, equipment, and methods used to actually prevent a fall from occurring, whereas fall protection is the process, equipment, and methods used to protect a worker once a fall has occurred. These philosophies are illustrated in Table 24.7. Each of these will be discussed individually.

Guardrails (29 CFR 1926.502)

Guardrails are the most used method to prevent a fall from occurring. The top edge height of top rails or equivalent guardrail system members shall be 42 ± 3 in. above the walking/working surface. Under certain conditions, when warranted, the top edge height may exceed 45 in. However, the guardrail system must still comply with all other requirements of 29 CFR 1926.502.

Note: When employees are using stilts, the top edge of the rail must be increased to an amount equal to the height of the stilts.

Midrails, screens, mesh, intermediate vertical members, or equivalent intermediate structural members shall be installed between the top edge of the guardrail system and the walking/working surface when there is no wall or parapet wall at least 21 in. high. Midrails, when used, shall extend from the top rail to the walking/working level and along the entire opening between top rail supports. Intermediate members, such as balusters, when used between posts, shall be no more than 19 in. apart. Other structural members (such as additional midrails and architectural panels) shall be installed such that there are no openings in the guardrail system that are greater than 19 in. wide.

Guardrail systems shall be capable of withstanding, without failure, a force of at least 200 lb applied within 2 in. of the top edge, in any outward or downward direction, at any point along the top edge. When the 200-lb test load is applied in a downward direction, the top edge of the guardrail shall not deflect to a height less than 39 in. above the walking/working level. Top rails and midrails shall be at least 1/4 in. nominal diameter or thickness to prevent cuts and lacerations. If wire rope is used for top rails, it shall be flagged at not more than 6-ft intervals with high-visibility material. When guardrail systems are used at hoisting areas, a chain, gate, or removable guardrail section shall be placed across the access opening between guardrail sections when hoisting operations are not taking place.

Positioning Device System (29 CFR 1926.502(e))

Restraint Systems

A restraint system prevents a worker from being exposed to any fall. If the employee is protected by a restraint system, either a body belt or a harness

may be used. When a restraint system is used for fall protection from an aerial lift or a boom-type elevating work platform, the employer must ensure that the lanyard and anchor are arranged so that the employee is not potentially exposed to falling *any* distance.

Positioning Devices: Construction Work

The only time a body belt may be used where there may be a fall is when an employee is using a "positioning device." In 29 CFR 1926.500 of the construction standards for fall protection, a "positioning device system" is defined as a body belt or body harness system rigged to allow an employee to be supported on an elevated vertical surface, such as a wall (or a pole), and work with both hands free while leaning. Therefore, in construction work, a positioning device may be used only to protect a worker on a *vertical* work surface. These devices may permit a fall of up to 2 ft. They may be used in concrete form work, installation of reinforcing steel, and certain telecommunications work. Since construction workers in bucket trucks, scissor lifts, and boom-type elevating work platforms are on a *horizontal* surface, a positioning device may not be used for those workers (OSHA Standard Interpretation—Dated August 14, 2000).

Positioning device systems shall be rigged such that an employee cannot free fall more than 2 ft and shall be secured to an anchorage capable of supporting at least twice the potential impact load of an employee's fall or 3000 lb, whichever is greater. Connectors shall be drop forged, pressed, or formed steel, or made of equivalent materials. Connectors shall have a corrosion-resistant finish, and all surfaces and edges shall be smooth to prevent damage to interfacing parts of the system. Connecting assemblies shall have a minimum tensile strength of 5000 lb. Dee-rings and snap hooks shall be proof-tested to a minimum tensile strength of 3600 lb without cracking, breaking, or taking permanent deformation. Unless the snap hook is a locking type and designed for the following connections, snap hooks shall not be engaged.

- Directly to webbing, rope, or wire ropes
- To each other
- To a D-ring to which another snap hook or other connector is attached
- To a horizontal lifeline
- To any object that is incompatibly shaped or dimensioned in relation to the snap hook such that unintentional disengagement could occur by the connected object being able to depress the snap hook keeper and release itself

Positioning device systems shall be inspected prior to each use for wear, damage, and other deterioration, and defective components shall be removed from service. Body belts, harnesses, and components shall be used only for employee protection and not to hoist materials.

Warning Line Systems (29 CFR 1926.502(f))

A warning line system means a barrier erected on a roof to warn employees that they are approaching an unprotected roof side or edge, and which designates an area in which roofing work may take place without the use of guardrails, body belt, or safety net systems to protect employees in the area. When warning line systems are used, they shall be erected around all sides of the roof work area. When mechanical equipment is not being used, the warning line shall be erected not less than 6 ft from the roof edge. When mechanical equipment is being used, the warning line shall be erected not less than 6 ft from the roof edge that is parallel to the direction of mechanical equipment operation and not less than 10 ft from the roof edge that is perpendicular to the direction of mechanical equipment operation.

Points of access, materials handling areas, storage areas, and hoisting areas shall be connected to the work area by an access path formed by two warning lines. When the path to a point of access is not in use, a rope, wire, chain, or other barricade, equivalent in strength and height to the warning line, shall be placed across the path at the point where the path intersects the warning line erected around the work area, or the path shall be offset such that a person cannot walk directly into the work area. Warning lines shall consist of ropes, wires, or chains and supporting stanchions erected as follows:

- The rope, wire, or chain shall be flagged at not more than 6-ft intervals with high-visibility material.
- The rope, wire, or chain shall be rigged and supported in such a way that its lowest point (including sag) is no less than 34 in. from the walking/working surface, and its highest point is no more than 39 in. from the walking/working surface.
- After being erected, with the rope, wire, or chain attached, stanchions shall be capable of resisting, without tipping over, a force of at least 16 lb applied horizontally against the stanchion, 30 in. above the walking/working surface, perpendicular to the warning line, and in the direction of the floor.
- The rope, wire, or chain shall have a minimum tensile strength of 500 lb and, after being attached to the stanchions, shall be capable of supporting, without breaking, the load applied to the stanchions.
- The line shall be attached at each stanchion in such a way that pulling on one section of the line between stanchions will not result in slack being taken up in adjacent sections before the stanchion tips over.

No employee shall be allowed in the area between a roof edge and a warning line unless the employee is performing roofing work in that area. Mechanical

equipment on roofs shall be used or stored only in areas where employees are protected by a warning line system, guardrail system, or PFAS.

Controlled Access Zone System (29 CFR 1926.502(g))

Controlled access zone means an area in which certain work (e.g., overhand bricklaying) may take place without the use of guardrail systems, PFASs, or safety net systems, and access to the zone is controlled. When used to control access to areas where leading edge and other operations are taking place, the controlled access zone shall be defined by a control line or by any other means that restricts access and shall be erected not less than 6 ft or not more than 25 ft from the unprotected or leading edge, except when erecting precast concrete members. When erecting precast concrete members, the control line shall be erected not less than 6 ft nor more than 60 ft or half the length of the member being erected, whichever is less, from the leading edge. The control line shall extend along the entire length of the unprotected or leading edge and shall be approximately parallel to the unprotected or leading edge. The control line shall be connected on each side to a guardrail system or wall. When used to control access to areas where overhand bricklaying and related work are taking place, the controlled access zone shall be defined by a control line erected not less than 10 ft nor more than 15 ft from the working edge. On floors and roofs where guardrail systems are in place but need to be removed to allow overhand bricklaying work or leading-edge work to take place, only that portion of the guardrail necessary to accomplish that day's work shall be removed.

Safety Monitoring System (29 CFR 1926.502(h))

A safety monitoring system consists of a competent person capable of recognizing fall hazards and who monitors the safety of other employees from the same walking/working surface. The safety monitor must be within visual sighting distance of the employee being monitored and close enough to communicate orally. Safety monitors should have no other responsibilities that could take their attention away from monitoring. The safety monitor is responsible for warning the employee when it appears that the employee is unaware of a fall hazard or is acting unsafely.

Personal Fall Arrest System (29 CFR 1926.502(d))

A PFAS is a system used to arrest an employee in a fall from a working level. It consists of an anchorage, connectors, and a body harness and may include a lanyard, deceleration device, lifeline, or suitable combinations of these. PFAS connectors shall meet the same requirements described in the Positioning Device System section. There are various types and components of a PFAS, including harnesses, lanyards, beam wraps, carabiners,

rope grabs, and so on. The main thing to remember concerning PFAS is that there is no "one-size-fits-all" solution. For example, if a worker is working 12 ft off the ground, a harness and a 6-ft shock-absorbing lanyard will not protect an employee from injury. Consider a 6-ft man and a 6-ft lanyard with a 3-ft shock absorber. The total length of the system is 15 ft. Therefore, the employee wearing this system at this height would actually hit the ground. There are numerous and varied fall protection products on the market. Check with the manufacturer to determine the specific uses and limitations before purchasing.

Suspension Trauma Related to Fall PFASs

Suspension trauma, also known as "harness hang" or "orthostatic incompetence," is the medical effect of immobilization in a vertical position. Suspension trauma presents an immediate threat of death to anyone immobilized in a vertical position. All persons working at heights and wearing PFASs should be trained in how to recognize, manage, and prevent suspension trauma. The danger of suspension trauma occurs only when an employee who experiences a fall is unable or unwilling to move.

Signs and symptoms of suspension trauma are as follows:

- General feeling of unease
- Dizzy, sweaty, and other signs of shock
- Increased pulse and respiratory rates
- Sudden drop in pulse and blood pressure
- Instant loss of consciousness
- Death, if not rescued, results from suffocation owing to a closed airway or from lack of blood flow and oxygen to the brain

The veins in your legs are intertwined within the skeletal muscles, and when you move your legs, these muscles squeeze the veins, pushing the blood out of the way. These veins have one-way valves, so each squeeze can pump the blood a short distance toward the heart. Providing you're moving around, these veins continue to pump blood. However, if you're immobilized, the muscles are not pumping blood upward, and the blood pools in the leg. The brain tries to "shock" the system for a while, but the blood still remains pooled in the legs. Eventually, the brain is deprived of oxygen and the person faints. Under normal circumstances, the fainting person goes from an upright position to a horizontal position and the blood begins to flow back toward the heart and brain. However, someone who has fallen in a body harness stays upright and therefore the brain is not receiving any oxygen supply, the airway becomes restricted, and death can occur after 10 min.Table 25.6

TABLE 25.6

Fall Prevention and Fall Protection Systems

Philosophy	Process, Equipment, or Methods
Fall prevention	• Guardrails
	• Restraint/positioning
	• Warning lines
	• Controlled access zones
	• Safety monitors
Fall protection	• Fall arrest systems
	• Safety nets

The answer to preventing death resulting from suspension trauma may seem simple. **R*escue must occur within 10 min.*** Rapid responsible rescue is needed. However, there is an issue known as "reflow syndrome" that must be dealt with. The pooled blood that is trapped in the legs may not be in very good condition and may even kill the person if it all pour back into the brain. Reflow syndrome is medically complicated. Once the blood begins to flow, it cannot be controlled, and the patient may die. Pooled blood in the legs is "stale" after 10–20 min, as it is drained of oxygen and saturated with carbon dioxide. It is also loaded with toxic waste. Once suspension trauma has occurred, the blood flow must trickle back into the system. Anyone released from immobile suspension should be kept in a sitting position for at least 30 min.

The question now arises, "How do we prevent suspension trauma?" If you're in a harness by choice, keep your legs moving as much as you possibly can and take regular rest breaks. If you fall accidentally and are suspended:

- Avoid using your legs. You don't want blood to be sent there.
- Lift your knees into a sitting position, or at least higher than your hips.
- Relax as much as possible. Panic makes things worse.
- If you can, every few minutes, swing yourself upside down.

If you're trapped and cannot move:

- Strain your leg muscles as hard as you can every 5 s.
- Breathe slowly and deeply.
- Await rescue.

Safety Net Systems (29 CFR 1926.502(c))

When using a safety net system, it should be installed as close as practicable under the walking/working surface on which employees are working, but in

TABLE 25.7

Minimum Required Horizontal Distance of Nets from Working Surfaces

Vertical Distance from Working Level to Horizontal Plane of Net	Minimum Required Horizontal Distance of Outer Edge of Net from the Edge of the Working Surface
Up to 5 ft	8 ft
>5 ft up to 10 ft	10 ft
>10 ft	13 ft

no case more than 30 ft below such level. Safety nets shall extend outward from the outermost projection of the work surface as described in Table 25.7.

Safety nets shall be installed with sufficient clearance under them to prevent contact with the surface or structures below when subjected to an impact force equal to the drop test. Safety nets and their installations shall be capable of absorbing an impact force equal to that produced by the drop test. Safety nets and safety net installations shall be drop tested at the job site after initial installation and before being used as a fall protection system, whenever relocated, after major repair, and at 6-month intervals if left in one place. The drop test shall consist of a 400-lb bag of sand 30 ± 2 in. in diameter dropped into the net from the highest walking/working surface at which employees are exposed to fall hazards, but not from less than 42 in. above that level. Defective nets shall not be used. Safety nets shall be inspected at least once a week for wear, damage, and other deterioration. Defective components shall be removed from service. Safety nets shall also be inspected after any occurrence that could affect the integrity of the safety net system.

Materials, scrap pieces, equipment, and tools that have fallen into the safety net shall be removed as soon as possible from the net and at least before the next work shift. The maximum size of each safety net mesh opening shall not exceed 36 in.^{2} nor be longer than 6 in. on any side, and the opening, measured center to center of mesh ropes or webbing, shall not be longer than 6 in. All mesh crossings shall be secured to prevent enlargement of the mesh opening. Each safety net shall have a border rope or webbing with a minimum breaking strength of 5000 lb. Connections between safety net panels shall be as strong as integral net components and shall be spaced not more than 6 in. apart.

Cranes and Derrick Safety (29 CFR 1926.550[4])

Cranes and derricks represent a significant hazard on any construction site. The specifics of cranes and derricks are voluminous. Therefore, this section is intended to provide the general requirements and practices for most cranes and derricks that may be used on any construction site.

First, the operator of any crane shall comply with the manufacturer's specifications and limitations. Rated load capacities, recommended operating speeds, and special hazard warnings or instructions shall be conspicuously

posted on all equipment. Instructions or warnings shall be visible to the operator while he or she is at his or her control station. Hand signals to crane and derrick operators shall be those prescribed by the applicable ANSI standard for the type of crane in use. An illustration of the signals shall be posted at the job site. The employer shall designate a competent person who shall inspect all machinery and equipment prior to each use, and during use, to make sure it is in safe operating condition. Any deficiencies shall be repaired, or defective parts replaced, before continued use. A thorough annual inspection of the hoisting machinery shall be made by a competent person or by a government or private agency recognized by the US Department of Labor. The employer shall maintain a record of the dates and results of inspections for each hoisting machine and piece of equipment.

Wire rope shall be taken out of service when any of the following conditions exist:

- In running ropes, six randomly distributed broken wires in one lay or three broken wires in one strand in one lay.
- Wear of one-third the original diameter of outside individual wires, kinking, crushing, bird caging, or any other damage resulting in distortion of the rope structure.
- Evidence of any heat damage from any cause.
- Reductions from nominal diameter of more than 1/64 in. for diameters up to and including 5/16 in., 1/32 in. for diameters 3/8 in. to and including 1/2 in., 3/64 in. for diameters 9/16 in. to and including 3/4 in., 1/16 in. for diameters 7/8 in. to 1 1/8 in. inclusive, and 3/32 in. for diameters 1 1/4 to 1 1/2 in. inclusive.
- In standing ropes, more than two broken wires in one lay in sections beyond end connections or more than one broken wire at an end connection.

Belts, gears, shafts, pulleys, sprockets, spindles, drums, flywheels, chains, or other reciprocating, rotating, or moving parts of equipment shall be guarded if such parts are exposed to contact by employees, or otherwise create a hazard. Accessible areas within the swing radius of the rear of the rotating superstructure of the crane, either permanently or temporarily mounted, shall be barricaded in such a manner as to prevent an employee from being struck or crushed by the crane. All exhaust pipes shall be guarded or insulated in areas where contact by employees is possible in the performance of normal duties.

Fuel tank filler pipes shall be located in such a position or protected in such a manner as to not allow spill or overflow to run onto the engine, exhaust, or electrical equipment of any machine being fueled. An accessible fire extinguisher of 5BC rating, or higher, shall be available at all operator stations or cabs of equipment.

Except where electrical distribution and transmission lines have been deenergized and visibly grounded at the point of work or where insulating barriers, not a part of or an attachment to the equipment or machinery, have been erected to prevent physical contact with the lines, equipment or machines shall be operated proximate to power lines only as listed in Table 25.8.

In transit with no load and boom lowered, the equipment clearance shall be a minimum of 4 ft for voltages less than 50 kV, 10 ft for voltages over 50 kV up to and including 345 kV, and 16 ft for voltages up to and including 750 kV.

Welding, Cutting, and Brazing (29 CFR 1926.350–353[6])

As a safety professional, it is incumbent that you have basic knowledge of welding, cutting, and brazing operations. Hazards associated with welding, cutting, and brazing operations are endless, including, but not limited to:

- Health hazards (air contaminants from welding operations [iron oxide, zinc, beryllium, copper, etc.], burns, burns to the eyes from flashes)
- Physical hazards (tripping from hoses)
- Fires and explosions (igniting gases, improper storage)

Therefore, the basics of welding operations will be discussed, with the primary focus being on the OSHA regulations. There are three basic types of welding, which include (1) oxygen-fuel gas welding and cutting, (2) arc welding and cutting, and (3) resistance welding.

Oxygen-Fuel Gas Welding and Cutting

Oxygen-fuel gas welding is a process that uses fuel gases to weld by heating metals to a temperature that produces a shared pool of molten metal, which cools into a common metal. Oxygen-fuel gas cutting is a process that uses fuel gases to cut metals by heating the metal to a temperature that produces molten metal, which is then "blown" away.

The general requirements for oxygen-fuel welding and cutting focus on the safe use of acetylene. Therefore, the following standards are provided when transporting, moving, and storing compressed gas cylinders:

TABLE 25.8

Minimum Clearance for Power Lines (Rating)

Line Rating	Minimum Clearance
50 kV or below	10 ft
>50 kV	10 ft plus 0.4 in. for each kilovolt over 50 kV

- When cylinders are hoisted, they shall be secured in a cradle, slingboard, or pallet. They shall not be hoisted or transported by means of magnets or choker slings.
- Cylinders shall be moved by tilting and rolling them on their bottom edges and shall not be intentionally dropped, struck, or permitted to strike each other violently.
- When cylinders are transported by powered vehicles, they shall be secured in a vertical position.
- Valve protection caps shall not be used for lifting cylinders from one vertical position to another. Bars shall not be used under valves or valve protection caps to pry cylinders loose when frozen. Warm, not boiling, water shall be used to thaw cylinders loose.
- Unless cylinders are firmly secured on a special carrier intended for this purpose, regulators shall be removed, and valve protection caps put in place before cylinders are transported.
- A suitable cylinder truck, chain, or other steadying device shall be used to keep cylinders from being knocked over while in use.
- When work is finished, when cylinders are empty, or when cylinders are moved at any time, the cylinder valve shall be closed.
- Compressed gas cylinders shall always be secured in an upright position except, if necessary, for short periods when cylinders are being hoisted or carried.
- Oxygen cylinders in storage shall be separated from fuel-gas cylinders or combustible materials (especially oil or grease) by a minimum distance of 20 ft or by a noncombustible barrier of at least 5 ft high, having a fire-resistance rating of at least 1/2 h.
- Inside buildings, cylinders shall be stored in a well-protected, well-ventilated, dry location at least 20 ft from highly combustible materials such as oil or excelsior. Cylinders should be stored in assigned places away from elevators, stairs, or gangways. Assigned storage places shall be located where cylinders will not be knocked over or damaged by passing or falling objects, or subject to tampering by unauthorized persons. Cylinders shall not be kept in unventilated enclosures such as lockers or cupboards.

The safe use of fuel gas requires that the employer thoroughly instruct employees in the safe use of fuel gas as follows:

- Before a regulator to a cylinder valve is connected, the valve shall be opened slightly and closed immediately. This action is generally termed "cracking" and is intended to clear the valve of dust or dirt that might otherwise enter the regulator. The person cracking the valve shall stand to one side of the outlet, not in front of it. The valve

of a fuel gas cylinder shall not be cracked where the gas could reach welding work, sparks, flame, or other possible sources of ignition.

- The cylinder valve shall always be opened slowly to prevent damage to the regulator. For quick closing, valves on fuel gas cylinders shall not be opened more than 1 1/2 turns.
- Fuel gas shall not be used from a cylinder through torches or other devices that are equipped with shutoff valves without reducing the pressure through a suitable regulator attached to the cylinder valve or manifold.
- Before a regulator is removed from a cylinder valve, the cylinder valve shall always be closed, and the gas released from the regulator.
- If, when the valve on a fuel gas cylinder is opened, a leak found around the valve stem, the valve shall be closed, and the gland nut tightened. If this action does not stop the leak, the use of the cylinder should be discontinued, and it should be properly tagged and removed from the work area.
- If a leak should develop at a fuse plug or other safety device, the cylinder should be removed from the work area.

Fuel Gas and Oxygen Manifolds (29 CFR 1926.350(e))

Fuel gas and oxygen manifolds shall bear the name of the substance they contain in letters at least 1 in. high, which shall be painted either on the manifold or on a sign permanently attached to it. Fuel gas and oxygen manifolds shall be placed in safe, well-ventilated, and accessible locations. They shall not be located within enclosed spaces. Manifold hose connections, including both ends of the supply hose that lead to the manifold, shall be such that the hose cannot be interchanged between fuel gas and oxygen manifolds and supply header connections. Adapters shall not be used to permit the interchange of hose. Hose connections shall be kept free of grease and oil. When not in use, manifold and header hose connections shall be capped.

Hoses (29 CFR 1926.350(f))

Fuel gas hoses and oxygen hoses shall be easily distinguishable from each other. The contrast may be made by different colors or by surface characteristics readily distinguishable by the sense of touch. Oxygen and fuel gas hoses shall not be interchangeable. A single hose having more than one gas passage shall not be used.

Torches (29 CFR 1926.350(g))

Clogged torch tip openings shall be cleaned with suitable cleaning wires, drills, or other devices designed for such purposes. Torches in use shall be

inspected at the beginning of each work shift for leaking shutoff valves, hose couplings, and tip connections. Defective torches shall not be used. Torches shall be lighted by friction lighters or other approved devices, and not by matches or other hot work.

Regulators and Gauges (29 CFR 1926.350(h))

Oxygen and fuel gas pressure regulators, including their related gauges, shall be in proper working order while in use.

Oil and Grease Hazards (29 CFR 1926.350(i))

Oxygen cylinders and fittings shall be kept away from oil or grease. Cylinders, cylinder caps and valves, couplings, regulators, hose, and apparatus shall be kept free from oil or greasy substances and shall not be handled with oily hands or gloves. Oxygen shall not be directed at oil surfaces and greasy clothes or within a fuel oil or other storage tank or vessel.

Arc Welding and Cutting

Arc welding or cutting is a fusion process wherein the coalescence of the metals is achieved from the heat of an electrode and formed between an element. Three key terms to be familiar with in this type of welding include *application, installation,* and *operation and maintenance.* Application applies to a large and varied group of processes that use an electric arc as the source of heat to melt and join metals. Proper installation of equipment is required for arc welding. A key safety component of the installation process is ensuring that proper grounding is completed. For the operation and maintenance of the arc welding equipment, all connections to the machine shall be checked to make certain that they are properly made.

Manual Electrode Holders (29 CFR 1926.351(a))

Only manual electrode holders that are specifically designed for arc welding and cutting and are of a capacity capable of safely handling the maximum rated current required by the electrodes shall be used. Any current-carrying parts passing through the portion of the holder, which the arc welder or cutter grips in his hand, and the outer surfaces of the jaws of the holder, shall be insulated against the maximum voltage encountered to ground.

Welding Cables and Connectors (29 CFR 1926.351(b))

All arc welding and cutting cables shall be of the completely insulated, flexible type, capable of handling the maximum current requirements of the work in progress, considering the duty cycle under which the arc welder or

cutter is working. Only cable free from repair or splices for a minimum distance of 10 ft from the cable end to which the electrode holder is connected shall be used, except that cables with standard insulated connectors or with splices whose insulating quality is equal to that of the cable are permitted. Cables in need of repair shall not be used.

Ground Returns and Machine Grounding (29 CFR 1926.351(c))

A ground return cable shall have a safe current-carrying capacity equal to or exceeding the specified maximum output capacity of the arc welding or cutting unit that it services. When a single ground return cable services more than one unit, its safe current-carrying capacity shall equal or exceed the total specified maximum output capacities of all the units that it serves.

Resistance Welding

Resistance welding utilizes pressure and heat that is generated in the pieces to be welded by resistance to an electrical current. When conducting resistance welding, all equipment shall be installed by a qualified electrician in conformance with 29 CFR 1926 Subpart S. If spot and seam welding machines are used, the following precautions must be taken:

- All doors and access panels of all resistance welding machines, and control panels shall be kept locked and interlocked to prevent access to live portions of the equipment by unauthorized persons.
- In all press welding operations, if there is a possibility of the operator's fingers being under the point of operation, effective guards must be used.

Fire Prevention (29 CFR 1926.352)

When practical, objects to be welded, cut, or heated shall be moved to a designated safe location or, if the objects to be welded, cut, or heated cannot be readily moved, all movable fire hazards in the vicinity shall be taken to a safe place, or otherwise protected. If the object to be welded, cut, or heated cannot be moved and if all the fire hazards cannot be removed, positive means shall be taken to confine the heat, sparks, and slag and to protect the immovable fire hazards from them. No welding, cutting, or heating shall be done where the application of flammable paints or the presence of other flammable compounds or heavy dust concentrations creates a hazard. Suitable fire extinguishing equipment shall be immediately available in the work area and shall be maintained in a state of readiness for instant use. For most companies, the welding, cutting, and brazing policy or procedure requires the use of a fire watch, which is to be present at all times of the operation, including 30 min after all "hot work" operations have been concluded.

Ventilation and Protection in Welding, Cutting, and Heating (29 CFR 1926.353[5])

Ensuring adequate ventilation in welding, cutting, and heating operations is extremely important since many of the metals being welded require special or specific control measures in order to prevent illnesses or other adverse health effects to the welder. These may include the following:

- Fluorine compounds
- Zinc
- Lead
- Beryllium
- Cadmium
- Mercury
- Cleaning compounds
- Stainless steel

General ventilation shall be of sufficient capacity and so arranged as to produce the number of air changes necessary to keep welding fumes and smoke within safe limits. Local exhaust ventilation shall consist of freely movable hoods intended to be placed by the welder or burner as close as practicable to the work. This system shall be of sufficient capacity and so arranged as to remove fumes and smoke at the source and keep the concentration of them in the breathing zone within safe limits. Contaminated air exhausted from a working space shall be discharged into the open air or otherwise clear of the source of intake air.

Hand and Power Tool Safety (29 CFR 1910 Subpart P[7])

OSHA requires that each employer be responsible for the safe condition of tools and equipment used by employees, including tools and equipment that may be furnished by employees. Employers shall not issue or permit the use of unsafe hand or power tools. Employees who use hand and power tools and who are exposed to the hazards of falling, flying, abrasive, and splashing objects or exposed to harmful dusts, fumes, mists, vapors, or gases must be provided with the personal protective equipment necessary to protect them from the hazard. Employees and employers have a responsibility to work together to establish safe working procedures. If a hazardous situation is encountered, it should be brought to the attention of the proper individual immediately.

Hand tools are nonpowered and include anything from axes to wrenches. The greatest hazards posed by hand tools result from misuse and improper maintenance. For example, dull chisels cause many accidents that could have

been avoided. Other hazards associated with the misuse or improper maintenance may include

- Using a screwdriver as a chisel, causing the tip of the screwdriver to break and hit an employee in the eye or cause a puncture wound.
- Wooden handles on hammers or axes may become loose and fly off and strike a bystander.
- A wrench whose jaws are sprung might slip, creating "busted knuckle."

Hand tools used around flammable substances may create sparks and serve as an ignition source. Where flammable substances are present or present the possibility of being ignited, non-sparking tools should be used. Non-sparking tools are manufactured from brass, bronze, Monel metal, copper aluminum alloys, copper-beryllium, and titanium. However, it must be noted that non-sparking tools have less tensile strength and may be more likely to break and wear more quickly than other tools. Therefore, frequent inspections to ensure proper maintenance are required.

All hazards involved in the use of power tools can be prevented by following the five basic safety rules:

- Keep all tools in good condition with regular maintenance.
- Use the right tool for the job.
- Examine each tool for damage before use.
- Operate all tools according to the manufacturer's instructions.
- Provide and use the proper personal protective equipment.

It would be extremely lengthy to discuss every hand or power tool available. A few of the more common power tools will be discussed in more detail and include abrasive grinders, portable circular saws, and compressed air systems.

Abrasive Grinders (29 CFR 1910.243)

Both portable and fixed grinding wheels are designed to operate at very high speeds. Shattered wheels can travel at several hundreds of miles per hour. Therefore, the potential for serious injury or property damage from the fragments is high. Employees operating grinding wheels must know the potential hazards, and more importantly, they should know the necessary precautions to prevent the occurrence of accidents.

The specific hazards associated with the use of grinding wheels include the following:

- Breathing in dusts from grinded metals.
- Contact with lubricating oils and metallic dusts can irritate the skin.

- Vibration can cause various ergonomic-related injuries, such as "white finger."
- Shattered wheels can cause physical injuries.
- Contact with a wheel in motion can cut, mangle, or even amputate a body part.
- Sparks from grinding metals can ignite nearby flammable materials.

Wheel Testing

Of particular importance to grinding wheels is the presence of cracks that may or may not be visible to the naked eye. There are two basic methods used to check for cracks in a grinding wheel. They are the "ring test" and the "vibration test."

The Ring Test

The ring test evaluates the sound coming from the wheel when lightly tapped with a nonmetallic material. An undamaged wheel sends out a clear ringing tone. The ring test should not be performed on wheels that have a diameter of 10 cm or less, plugs and cones, mounted wheels, segment wheels, or inserted nut and projecting stud disc wheels. To perform the ring test, follow the steps listed below:

- Suspend the wheel from the hole on a small pin or finger. If the wheel is too heavy, rest it on its outer edge on a clean, hard floor.
- Tap the wheel gently with a nonmetallic tool. For light wheels, use the wooden handle of a screwdriver. For heavy wheels, use a wood mallet. The best spot to tap a wheel is approximately 45° from either side of the vertical centerline, approximately 2.5–5 cm (1–2 in.) from the outside edge. Tapping on the centerline, even an undamaged wheel may give off a muffled sound.
- Listen for the sound that comes from the wheel when it is tapped.
- Turn the wheel 45° to the right or left and repeat the test.
- Compare the sounds from the wheel being tested with those from other wheels of the same lot and type.
- Set aside any wheel that is suspect.

The Vibration Test

The vibration test evaluates how dry sand moves on the side of a vibrating wheel. If the wheel is in good condition, the sand will remain evenly spread out over the entire surface of the wheel. Use the vibration test on all bonded

wheels. Unlike the ring test, the vibration test can be performed in noisy areas.

To perform the vibration test, follow these steps:

- Set the abrasive wheel on its side on a test fixture.
- Coat the wheel with a thin layer of fine, dry sand.
- Turn on the test fixture to get the wheel to gently vibrate.
- Watch the grains of sand as the wheel vibrates. If the sand moves away from an area of the wheel, this indicates a crack. If the sand remains evenly distributed, the wheel is acceptable.
- Repeat these steps for the other side of the wheel.

Understand that both the ring test and the vibration test are not 100% accurate. Therefore, it is necessary when grinding that all persons stand clear of any grinding operations.

Portable Circular Saws (29 CFR 1910.243)

In the construction industry, probably the most used power tool is the portable circular saw. Unfortunately, it is also one of the most abused tools. Familiarity with its use can cause carelessness on the part of the user. The following are specific safety practices that must be followed when using portable circular saws:

- Always use the appropriate personal protective equipment including safety glasses or goggles with side shields that comply with the current standard. In addition to safety glasses or goggles, a face shield is highly recommended. The use of hearing protection is also required.
- Do not wear loose clothing, jewelry, or dangling objects, including long hair, which may catch on rotating parts or accessories.
- Do not use a circular saw that is too heavy for you to easily control.
- Be sure that the switch actuates properly and never tape the switch or "trigger" down on any power tool.
- Use sharp blades. Dull blades can cause binding, stalling, or kickback.
- Use the correct blade for the application.
- Always inspect the portable circular saw prior to use to ensure that all safety features provided by the manufacturer are installed, including the blade guard. Be sure to inspect the power cord and ensure that it is connected in proper order to a GFCI.

- For maximum control of the circular saw, be sure to operate it with both hands.
- Avoid cutting small pieces that cannot be properly secured and material on which the saw cannot rest.
- ALWAYS ensure that the surface you are cutting on is stable. NEVER hold or balance a piece of material in one hand, while trying to operate the circular saw with the other.

Compressed Air Systems (29 CFR 1910.242)

Pneumatic tools used on a construction site are powered by compressed air and can include chippers, drills, hammers, and sanders. The dangers associated with the use of pneumatic tools and compressed air systems include getting struck by one of the tool's attachments or fastener that the employee is using with the tool, such as nails in a nail gun. Other hazards exist because of carelessness or misuse on the part of the operator. For example, one of the more frequent violations is the taping down of the triggers (especially on pneumatic hammers or nailers). NEVER bypass a safety feature and ALWAYS follow the manufacturer's operating specifications.

Using pneumatic tools requires an efficient compressor system to adequately power the tools. Use the following guidelines to properly maintain an efficient compressor system:

- Before making or breaking any air connection, always turn off the air supply. Use the valve to turn off the air and never "kink" the hose as a shortcut.
- Protect the air hose from damage.
- Be sure to use the proper size air hose and fittings to keep air pressure at a maximum throughout the entire line.
- Clear any dirt off the nipple before connecting the air hose to the tool.
- When the tool is connected, check the hose and all connections for leaks or damage before using the tool.
- Maintain a clean, dry, regulated source of air to operate air tools at peak performance.

Whenever there is compressed air used on a work site, employees invariably attempt to utilize the air from the system to "clean" or blow off the area or even on their persons. OSHA states in 29 CFR 1910.242(b), "Compressed air shall not be used for cleaning except where reduced to less than 30 psi (pounds per square inch)."

Housekeeping (29 CFR 1926.25[8])

One of the most common conditions, and one of the most cited, on a work site is poor general housekeeping. The benefits of good housekeeping include the following:

- Eliminating accident and fire hazards
- Maintaining safe, healthy work conditions
- Saves time, money, materials, space, and effort
- Improved productivity and quality
- Boosts morale of employees
- Reflects a well-run organization

The costs associated with poor housekeeping include the following:

- Slips, trips, and falls
- Fires
- Chemical and machine accidents
- Injuries from electrical problems
- Collisions and falling objects
- Health problems

OSHA's standard on housekeeping requires the following:

- During construction, alteration, or repairs, form and scrap lumber with protruding nails, and all other debris, shall be cleared from work areas, passageways, and stairs, in and around buildings or other structures.
- Combustible scrap and debris shall be removed at regular intervals during the course of construction. Safe means shall be provided to facilitate such removal.
- Containers shall be provided for the collection and separation of waste, trash, oily and used rags, and other refuse. Containers used for garbage and other oily, flammable, or hazardous wastes, such as caustics, acids, harmful dusts, and so on, shall be equipped with covers. Garbage and other waste shall be disposed of at frequent and regular intervals.

Key Information to Remember on Construction Safety

1. Excavations must be protected from cave-in if a trench is more than 4 ft deep.
2. Soil classifications are A, B, and C. Soil Type A is good cohesive soil with a high compressive strength. Soil Type B is cohesive soil with a moderate compressive strength, and Soil Type C is cohesive soil with low compressive strength.
3. Electrical current as low as 75 mA can cause death.
4. Bonding is connecting two or more conductive objects with a conductor.
5. Grounding is connecting one or more conductive objects directly to the earth using ground rods, cold pipes, or building steel.
6. Scaffolding requirements are addressed in 29 CFR 1926.450–454.[4]
7. Anchor points for personal fall arrests should be capable of holding 5000 lb per person.
8. Cranes and derricks must be clear of power lines by at least 10 ft for voltages up to 50 kV or 10 ft plus 0.4 in. for each kilovolt over 50 kV.
9. It is the employer's responsibility to ensure that only well-maintained and operable hand and power tools are utilized on the job site.
10. When using abrasive grinders, either the ring test or the vibration test must be performed on the wheel prior to using.
11. Only compressed air less than 30 psi may be used for cleaning operations.
12. Good housekeeping practices outlined in 29 CFR 1926.25[8] should be adhered to on all projects.

References

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26

Risk Assessment and Management

Every safety professional should be familiar with the risk management process. After all, managing risks is one of the primary functions of the safety professional. Risk management can be defined as the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and impact of unfortunate events or to maximize the realization of opportunities. Risks to a company can come from a wide variety of sources, including financial, natural disasters, intentional acts by employees or outside personnel, employee injuries, and others. Risks from employee injuries will be the primary focus of this chapter. There are a wide variety of specific methods used in risk management depending on the type of industry or service where the risk is being assessed. However, in this chapter, the five basic steps of risk management are discussed. Examples are provided to illustrate both quantitative and qualitative assessments.

Definitions

Risk: The chance or probability of occurrence of an injury, loss, or a hazard or potential hazard.

Risk assessment: The process of assessing the risks associated with each identified hazard in order to make decisions and implement appropriate control measures to prevent the hazard from occurring.

Hazard: A condition with the potential to cause injury, illness, or death of personnel; damage to or loss of equipment or property; or mission degradation.

Hazard identification: The process of examining each work area to identify the hazards associated with each job or task.

Probability: The likelihood that a given event will occur.

Severity: The degree of undesired consequences.

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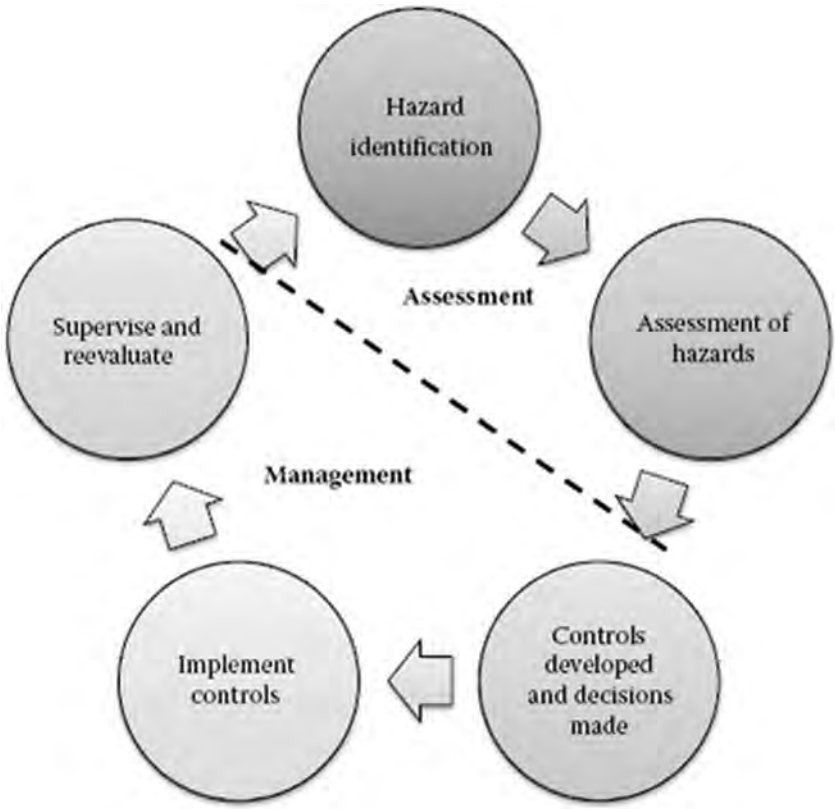


FIGURE 26.1
Risk management process (Source: Yates, W. David 2019).

Risk Management Process

In this chapter, the risk management process in terms of five basic steps, which are illustrated in Figure 26.1, will be discussed.

Each of these steps is discussed in more detail within the scope of this chapter.

Hazard Identification

As mentioned previously, a hazard is an actual or potential condition, situation, or event that can result in injury, illness, or death of personnel. In addition, a hazard can result in damage, loss, or destruction of equipment or a serious degradation of capabilities or total failure of the project or mission. Hazards are found in all environments and in all situations. Hazards are

identified through experience, historical data, intuitive analysis, judgment, standards, brainstorming, and a large variety of other means and methods. Hazard identification is, without a doubt, the most important step in the risk management process. It must also be noted that hazard identification is a continuous process and should be repeated throughout the work period. The specific method of hazard identification will change from site to site and from task to task. However, the basic process to systematically identify hazards in the workplace includes the following:

- Identify specific work areas.
- Review previous documents or data involved in the operation to determine if prior injuries or accidents have occurred as a result of this task.
- Conduct an on-site visual inspection of the work area.
- Determine the individual job tasks of individuals.
- Break the individual job tasks into steps.
- Analyze each job task and identify the hazards or potential hazards involved in performing these tasks.

An important step, often overlooked, is to involve the employee performing the actual work in the hazard identification process. No one knows more about the job task being performed than the employee performing the work. Useful information that may save lives or prevent property and equipment damage can be obtained.

Hazard Assessment

Once all known hazards have been identified, they must be assessed in terms of their probability and severity to determine the risk level of one or more of the hazardous incidents that can result from exposure to the hazard. In this step of the process, the hazards are assessed individually. This process is systematic in nature and uses charts, codes, and numbers to present a methodology to assess probability and severity to obtain a standardized risk level. *The charts and graphs presented in this chapter are only included to illustrate the risk management process and its uses. They can be modified to fit your individual needs.* The incident must be credible in that it must have a reasonable expectation of happening. The end result is an estimate of risk from each hazard and an estimate of the overall risk to the job task or project caused by hazards that cannot be eliminated.[1]

Two major components in the hazard assessment step are the *probability* of the hazard occurring and the *severity* of the hazard. As we have mentioned in this chapter, *probability* is defined as the likelihood that a given event or incident will occur. The incident must be credible in that it must have a reasonable expectation of happening. The result is an estimate of risk from each

TABLE 26.1

Hazard Probability Rating

Probability Rating	Description
Frequent (A)	*Occurs very often, known to happen regularly. For example, out of 500 exposures, it will happen at least once (numerically, 1/500)*
Likely (B)	*Occurs several times, a common occurrence. For example, out of 1000 exposures, it could happen once (numerically, 1/1000).*
Occasional (C)	*Occurs sporadically, but is not uncommon. You may or may not complete a job or project without this incident occurring to someone*
Seldom (D)	*Remotely possible, could occur at some time. Usually, several things must go wrong in order for it to occur.*
Unlikely (E)	*Can assume that the incident will not occur.*

Source: United States Army, July 2006. *FM No. 5-19 (Formerly FM 100-14), Composite Risk Management*. https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN34181-ATP_5-19-000-WEB-1.pdf.

hazard and an estimate of the overall risk to the job task or project caused by hazards that cannot be eliminated.[1] *Severity*, for our purposes, can be defined as the degree of undesired consequences.

Probability

Probability is the likelihood of an event occurring. This is a subjective estimate of the probability, given the information that you know. The probability levels estimated for each hazard are based on the job or project being performed at the time. There are five levels of probability that we will use in our assessment of the hazards. They include the following ratings: frequent, likely, occasional, seldom, and unlikely. A description of each of these is listed in Table 26.1.

Severity

Severity is expressed in terms of the degree to which an incident will affect the safety and health of employees or the project being performed. The degree of severity is somewhat subjective but is estimated for each hazard based on the knowledge of results from similar past events. Four levels of severity are illustrated in Table 26.2

As mentioned previously in this section, the end result is an estimate of risk from each hazard and an estimate of the overall risk to the job task or project caused by hazards that cannot be eliminated. Table 24.3 illustrates a risk assessment of both the probability and severity of the hazards using a ranking system of extremely high risk, high risk, moderate risk, and low risk.

Once all hazards have been identified and a risk assessment has been performed on each hazard, the highest level of risk will determine the overall

TABLE 26.2

Severity Rating

Severity Rating	Description
Catastrophic	*Death or permanent total disability; complete project failure or the loss of ability to complete the project; loss of major critical systems or equipment; severe environmental damage, unacceptable collateral damage.*
Critical	*Permanent partial disability or temporary total disability of employees; severely degraded project capability; extensive major damage to equipment or systems; significant property or environmental damage and significant collateral damage*
Marginal	*Lost work day injuries or illnesses; degraded project capabilities; minor damage to equipment or systems; or minor damage to the environment.*
Negligible	*First aid or minor medical treatment; little or no adverse impact on project capability; slight equipment or system damage, but fully functional or serviceable; little or no property or environmental damage.*

Source: United States Army, July 2006. *FM No. 5-19 (Formerly FM 100-14), Composite Risk Management.* https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN34181-ATP_5-19-000-WEB-1.pdf.

TABLE 26.3

Risk Assessment Matrix

		Probability				
Severity	**Category**	**Frequent (A)**	**Likely (B)**	**Occasional (C)**	**Seldom (D)**	**Unlikely (E)**
Catastrophic	*I*	*E*	*E*	*H*	*H*	*M*
Critical	*II*	*E*	*H*	*H*	*M*	*L*
Marginal	*III*	*H*	*M*	*M*	*L*	*L*
Negligible	*IV*	*M*	*L*	*L*	*L*	*L*

Source: United States Army, July 2006. *FM No. 5-19 (Formerly FM 100-14), Composite Risk Management.* https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN34181-ATP_5-19-000-WEB-1.pdf.

Note: E, extremely high risk; H, high risk; L, low risk; M, moderate risk.

risk assessment. Executive management should determine the level of risk the company should assume. For example, the decision to proceed with a low-risk project/task can be made by a line supervisor, whereas an extremely high-risk decision is to be made by the chief executive officer within the organization. When all risks are considered, the overall risk should be the highest risk level in the hazard assessment.

Risk Assessment Scenario

Using the following scenario, we will perform a risk assessment. Company XYZ has been contracted to provide industrial cleaning services, which involves the high-pressure water jetting of tube bundles within a condenser.

TABLE 26.4

Hazard Identification Worksheet

Location: Plant ABC
Date: March 29, 2010 Prepared by: Bill Smith

Hazard Identification	Probability	Consequence	Risk Rating
Back strains from manual lifting during loading and unloading of vehicles	*Frequent*	*Marginal*	*High*
Abrasions and lacerations resulting from pinch points and metals	*Frequent*	*Negligible*	*Moderate*
Vehicular accident during travel to and from the project site	*Seldom*	*Catastrophic*	*High*
Water blasting and jetting injuries resulting from "whipping" nozzles	*Occasional*	*Critical*	*High*
Eye injuries from flying debris	*Frequent*	*Critical*	*Extremely high*
Injuries from rolling vehicles	*Seldom*	*Critical*	*Moderate*
Total rating (highest in each category)	*Frequent*	*Catastrophic*	*Extremely high*

The process involves project mobilization, project setup, performance of high-pressure water jetting, project cleanup, and demobilization. We will look at some of the major hazards associated with this project for illustration purposes, but the list in Table 26.4 is not to be considered as all-encompassing. The first step in the risk management process is to identify all hazards.

Qualitative Analysis

On the basis of the initial assessment, the highest rating in each category resulted in this project being an extremely high rating. One of the things to remember in regard to a simplified risk assessment rating system is that the rater determines the rating. No two raters will rate each category the same. For example, one rater may determine that the probability of the occurrence is "frequent," while another may rate it as "likely" or "occasional." Neither one would be wrong if they based their decisions on the criteria listed previously. More in-depth methods may attempt to quantify each method to reduce the variations in assessments. As you can see from the above assessment, most projects will have one or more of the hazards listed as an "extremely high risk." If this were the case, most managers would not attempt to assume that level of risk, which means that little or no work would ever be accomplished. Therefore, step 3 in the process is intended to reduce the level of risk by implementing controls and making decisions.

	LO – Likelihood of Occurrence
0.03	Almost Impossible – Only in extreme circumstances
1	Highly Unlikely – Though conceivable
1.5	Unlikely-But could occur
2	Possible-But unusual
5	Even Chance – Could happen
8	Probable – Not surprising
10	Likely-To be expected
15	Certain – No doubt
	FE (Frequency of Exposure)
0.5	Annually
1	Monthly
1.5	Weekly
2.5	Daily
4	Hourly
5	Constantly
	DPH (Degree of Possible Harm)
0.1	Scratch/Bruise
0.5	Laceration or mild ill-effect
2	Break of minor bone or minor illness (temporary)
4	Break of major bone or major illness (temporary)
6	Loss of one limb, eye, hearing (permanent)
10	Loss of two limbs or eyes (permanent)
15	Fatality
	NP (Number of Persons at Risk)
1	1-2 persons
2	3-7 persons
4	8-15 persons
8	16-50 persons
12	50+ persons
	Hazard Risk Number =(LO x FE x DPH x NP)
0-5	Negligible
6-49	Low
50-249	Medium
250-500	High
[illegible]	[illegible]

FIGURE 26.2
Risk assessment codes (Source: Yates, W. David 2019).

Quantitative Analysis

Another method frequently used to assess hazards is through quantitative analysis. The following is an example of such analysis. Numerical values are placed on variables, such as the likelihood of occurrence, frequency of exposure, degree of potential harm, and the number of persons at risk. An example of this is shown in Figure 26.2.

Controls Development and Decision-Making

As mentioned in the previous step, most projects or tasks have at least one step that has an extremely high risk, which is unacceptable to almost everyone. Therefore, in this phase of the risk management process, it is necessary to develop controls to reduce the level of risk posed by the hazards. After assessing each hazard, supervisors and managers develop one or more controls that either eliminate the hazard or reduce the risk of a hazardous

RISK ASSESSMENT (BEFORE CONTROLS)						
Task or Condition	LO	FE	DPH	NP	HRN	Risk Level (Before)
Back strains from manual lifting during loading and unloading of vehicles.	5	2.5	6	3	225	High
Abrasions and lacerations resulting from pinch points.	5	2.5	0.5	3	19	Low
Vehicular accident during travel to and from the project site	5	2.5	15	3	563	Extremely High
Water blasting and jetting injuries resulting from "whipping" nozzles.	5	2.5	6	1	120	Medium
Eye injuries from flying debris.	5	2.5	6	2	150	Medium
Injuries from rolling vehicles.	5	2.5	15	3	563	Extremely High

RISK ASSESSMENT (AFTER CONTROLS)						
Task	LO	FE	DPH	NP	HRN	Risk Level (Before)
Back strains from manual lifting during loading and unloading of vehicles.	1.5	2.5	6	3	68	Medium
Abrasions and lacerations resulting from pinch points.	1	2.5	0.5	3	4	Negligible
Vehicular accident during travel to and from the project site	2	2.5	15	3	225	Medium
Water blasting and jetting injuries resulting from "whipping" nozzles.	0.03	2.5	6	1	0.5	Negligible
Eye injuries from flying debris.	1.5	2.5	6	2	45	Low
Injuries from rolling vehicles.	1.5	2.5	15	3	169	Medium

FIGURE 26.3
Quantitative assessment (before and after controls) (Source: Yates, W. David 2019).

incident. When developing controls, the supervisors or managers consider the reason for the hazard, not just the hazard itself.

Types of Controls

The types of controls can take many forms, but fall into three main categories: *educational controls, physical controls,* and *avoidance.*

- *Educational controls:* These controls are based on the knowledge and skills of the employees or individuals performing the task. Effective control is implemented through individual and collective training that ensures performance to a standard.

- *Physical controls*: These controls may take the form of barriers and guards or signs to warn employees and others that a hazard exists. Additionally, special controllers or supervisory personnel responsible for locating specific hazards fall into this category.
- *Avoidance.* These controls are applied when supervisors and managers take positive action to prevent contact or exposure to the identified hazard.

Criteria for Controls

To be effective, each control developed must meet the following criteria:

- *Support*: Availability of adequate personnel, equipment, supplies, and facilities necessary to implement suitable controls.
- *Standards*: Guidance and procedures for implementing a control are clear, practical, and specific.
- *Training*: Knowledge and skills are adequate to implement a control.
- *Leadership*: Supervisors and managers are competent to implement controls.
- *Individual*: Individual employees are sufficiently self-disciplined to implement a control measure.[2]

Some examples of control measures include the following:

1. Engineering or designing to eliminate or control hazards
2. Avoidance of identified hazards
3. Limiting the number of personnel and the amount of time they are exposed to hazards
4. Providing protective clothing, equipment, and safety devices
5. Providing warning signs and signals

A key element in developing and implementing control measures is to specify who, what, when, where, and how each control is to be used. Taking the scenario above under the heading Controls Development and Decision-Making section, we will continue to expand upon the worksheet to illustrate the development of controls. Table 26.5 illustrates the reevaluation of hazards after control measures have been developed.

As you can see in Table 26.5, after controls have been developed, the hazards and, subsequently, the risks associated with this project or task have been reduced to a moderate risk. This level of risk is acceptable to most managers and supervisors. Once the control measures have been accepted, the responsible level of authority determines the overall residual risk, as listed

TABLE 26.5

Example Risk Assessment Table

Hazard Identification	Controls	Probability	Consequence	Risk Rating
Back strains from manual lifting during the loading and unloading of vehicles	1. Toolbox talks 2. Buddy system when loading and unloading 3. Use of materials handling equipment (mechanical)	Seldom	Marginal	Low
Abrasions and lacerations resulting from pinch points and metals	1. Use of personal protective equipment (i.e., gloves) 2. Toolbox talks	Seldom	Negligible	Low
Vehicular accident during travel to and from the project site	1. Driver training 2. Supervisors ensuring that drivers are not fatigued 3. Toolbox talks	Seldom	Critical	Moderate
Water blasting and jetting injuries resulting from "whipping" nozzles	1. Protective clothing including body armor suits 2. Use of ant withdrawal devices 3. Toolbox talks	Unlikely	Critical	Low
Eye injuries from flying debris	1. Wearing of face shields and goggles 2. Toolbox talks	Seldom	Marginal	Low
Injuries from rolling vehicles	1. Use of wheel chocks 2. Toolbox talks 3. Enforce emergency brake usage	Unlikely	Critical	Low
Total rating (highest in each category)		Seldom	Critical	Moderate

in Table 26.5. The residual risk is defined as the risk remaining after controls have been selected for the hazards.[2]

Decision-Making

A key element of the risk decision is determining if the risk is justified. The supervisor or manager responsible for the project must compare and balance the risk against the benefits. If the residual levels are too high, then the senior supervisor or manager on the project may elect to do one of the following:

- Add additional control measures to further reduce the risks.
- Limit the scope of work, which eliminates the high-risk tasks.
- Make the decision to discontinue the project.

Implement Controls

Managers and supervisors must ensure that controls are integrated into the standard operating procedures, written and verbal instructions, and toolbox talks prior to the beginning of the project or task. The critical check for this step, with oversight, is to ensure that controls are converted into clear, simple instructions understood at all levels. Implementing controls includes coordination and communication with appropriate superiors and employees.

Supervise and Evaluate

During project or task preparation, managers and supervisors must ensure that employees understand how to execute the risk controls. In addition, the manager or supervisor of the project or task must continually assess the risks during the operational phase of the project. Methods to supervise and evaluate the effectiveness of control measures include spot checks, inspections, daily reports, and close, direct supervision. After the project or task has been completed, it is recommended that a post-project evaluation, which includes all employees on the project, be conducted. The results of this post-project evaluation, and any changes, should be maintained in the project file for future use.

Key Information to Remember on Risk Assessment and Management

1. Risk is defined as the chance or probability of the occurrence of an injury, loss, hazard, or potential hazard.

2. Risk assessment is the process of assessing the risks associated with each identified hazard, to make decisions and implement appropriate control measures to prevent the hazard from occurring.
3. Hazard is a condition with the potential to cause injury, illness, or death of personnel; damage to or loss of equipment or property; or mission degradation.
4. Hazard identification is the process of examining each work area to identify the hazards associated with each job or task.
5. Probability is defined as the likelihood that a given event will occur.
6. Severity is defined as the degree of undesired consequences.
7. The five basic steps in the risk management process are *hazard identification*, *hazard assessment*, *development of controls and decision-making*, *implementation*, and *supervision and evaluation*.
8. The types of controls can take many forms, but fall into three main categories: *educational controls*, *physical controls*, and *avoidance*.
9. A key element in developing and implementing control measures is to specify who, what, when, where, and how each control is to be used.
10. A key element of the risk decision is determining if the risk is justified.
11. The critical check for controls implementation, with oversight, is to ensure that controls are converted into clear, simple instructions understood at all levels.

Reference

1. United States Army. 2006. *FM No. 5-19 (Formerly FM 100-14), Composite Risk Management.* Available at http://www.cid.army.mil/documents/Safety/Safety%20ReferencesFM%205-19%20Composite%20Risk%20Management.pdf.

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Hazardous Materials Management

One of the most difficult areas in the safety profession to manage is one concerning hazardous materials. The difficulty arises from the process of almost-continuous hazardous materials inventory and control of incoming hazardous materials. However, this task is not without hope. In this chapter, the hazards associated with chemicals, impacts of hazardous materials, fundamentals of hazardous materials management, hazardous materials disposal, hazardous materials response procedures, and substances with special standards are discussed. The information available on hazardous materials management is voluminous. Therefore, information provided in this chapter is basic and superficial. It is intended to provide the Associate Safety Professional/Certified Safety Professional candidate with information to understand the basic requirements of a hazardous materials management program.

Hazardous Materials

What is a hazardous material? A hazardous material (Hazmat or HAZMAT) is any solid, liquid, or gas that can harm people, other living organisms, property, or the environment. The term *hazardous material* is used in this context almost exclusively in the United States. The equivalent term in the rest of the English-speaking world is *dangerous goods.* A hazardous material may be radioactive, flammable, explosive, toxic, corrosive, a biohazard, an oxidizer, an asphyxiant, or an allergen, or may have other characteristics that make it hazardous in specific circumstances.[1]

Hazardous Waste

Hazardous waste is defined as a "solid waste" that, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may

- Pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, disposed of, or otherwise mismanaged.

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- Cause or contribute to an increase in mortality or an increase in irreversible or incapacitating illness.

A solid waste is defined as any discarded material that is abandoned by being disposed of, burned or incinerated, recycled, or considered "waste-like." A solid waste can physically be a solid, liquid, semisolid, or a container of gaseous material.[2]

Basic Chemistry Review

In order to understand hazardous materials and hazardous wastes, and subsequently their management, the safety professional must have a basic understanding of chemicals and chemistry. As we have all learned, all matter is classified according to its physical state, which is solid, liquid, or gas.

Solid

A solid is characterized by structural rigidity and resistance to changes in shape or volume. Unlike a liquid, a solid object does not flow to take on the shape of its container, nor does it expand to fill the entire volume available to it like a gas does. The atoms in a solid are tightly bound to each other, either in a regular geometric lattice (crystalline solids, which include metals and ordinary water ice) or irregularly (an amorphous solid such as common window glass).

Liquid

Liquid is one of the three classic states of matter. Like a gas, a liquid is able to flow and take the shape of a container, but, like a solid, it resists compression. Unlike a gas, a liquid does not disperse to fill every space of a container and maintains a fairly constant density.

Gas

Gas is one of three classic states of matter. Near absolute zero, a substance exists as a solid. As heat is added to this substance, it melts into a liquid at its melting point, boils into a gas at its boiling point, and, if heated high enough, would enter a plasma state in which the electrons are so energized that they leave their parent atoms from within the gas. A pure gas may be made up of individual atoms (e.g., a noble gas or atomic gas like neon), elemental molecules made from one type of atom (e.g., oxygen), or compound molecules made from a variety of atoms (e.g., carbon dioxide). A gas mixture would

contain a variety of pure gases much like the air. What distinguishes a gas from liquids and solids is the vast separation of the individual gas particles.

Plasma

A fourth state of matter is plasma, which is only mentioned as it is considered distinct from a gas. Plasma is a gas in which a certain portion of the particles are ionized. The presence of a nonnegligible number of charge carriers makes the plasma electrically conductive so that it responds strongly to electromagnetic fields. Plasma, therefore, has properties quite unlike those of solids, liquids, or gases and is considered to be a distinct state of matter. Like gas, plasma does not have a definite shape or a definite volume unless enclosed in a container; unlike gas, in the influence of a magnetic field, it may form structures such as filaments, beams, and double layers.

Atomic Mass

As we discussed in Chapter 3, the atomic mass or weight of an atom includes protons, neutrons, and electrons. This weight is measured in grams. The atomic weight of any element is the average weight compared to carbon. The mass in grams of any element that is equal to that element's atomic weight is called 1 gram-molecular weight, or 1 mole (6.02×10^{23} atoms = Avogadro's number).

Atoms

Also discussed in Chapter 3, an atom is the basic unit of all matter, which contains a nucleus. The nucleus contains positively charged protons and neutrally charged neutrons. Surrounding the nucleus is a cloud of negatively charged electrons. Refer to Chapter 3 for a review of the atom.

Definitions Related to Matter

Density: The density of matter is equal to its mass per unit volume ($d = m/v$).

Specific gravity: The ratio of the density of a material to the density of water $\left(SG_X = d_x / d_{H_2o}\right)$. Those substances with a specific gravity of <1 are considered lighter than water and will float, while those with a specific gravity of >1 will sink.

Vapor density: Weight of a unit volume of gas or vapor compared to the weight of an equal volume of air (or, sometimes, hydrogen). Substances with vapor densities <1 are lighter than air, and those with vapor densities >1 are heavier than air. All gases and vapors

mix with air; the lighter substances tend to rise and dissipate, and the heavier substances tend to concentrate in low places along floors, sewers, and trenches and may create fire and health hazards.

Solubility: Solubility is the property of a solid, liquid, or gaseous chemical substance called a solute to dissolve in a liquid solvent to form a homogeneous solution. The solubility of a substance strongly depends on the used solvent as well as on temperature and pressure. Water solubility is usually measured in parts per million.

Periodic Table of the Elements

Refer to Chapter 3 for a detailed discussion on the Periodic Table of Elements. Currently, there are 118 individual elements listed on the table. The table lists the element's symbol, atomic number, atomic mass (grams), and the isotopes.

Measurements of Concentrations

Hazardous chemical concentrations are usually measured in parts per million, parts per billion, or milligrams per cubic meter. In Chapter 5, we discussed the calculations for each of these. For more information, refer to Chapter 5.

Hazardous Materials/Hazardous Waste Properties

In this section, the properties that make any material hazardous will be discussed. Anyone who has taken a basic college course in toxicology has heard the term, "the dose makes the poison." This is true for all substances, including water. By drinking too much water, you can overhydrate and cause water intoxication. Hazardous materials and hazardous wastes also have physical hazards that we will also discuss in this section.

Physical Hazards

Physical hazards associated with materials/waste include engulfment, overpressurization, slips, trips, and falls, crushing hazards, fire and explosion hazards, corrosion hazards, thermal decomposition, and water reactivity hazards. Each of these is discussed in more detail.

Engulfment

Engulfment results when a worker is surrounded and overcome by a granular substance such as soil, sand, gravel, sawdust, seed, grain, or flour, or if submerged in a liquid such as water or a chemical. Engulfment causes physical harm when the material has enough force on the body to cause injury or death by constriction, crushing, or strangulation. Respiratory hazards associated with engulfment include suffocation from breathing in a fine substance that fills the lungs or from drowning in a liquid. When working in confined spaces, it is important to strictly adhere to the Occupational Safety and Health Administration's confined space requirements (29 CFR 1910.146) and control of hazardous energy requirements (29 CFR 1910.147). By fully complying with these regulations, the risk of engulfment can be minimized.

Over-pressurization

Over-pressurization can occur as a result of an increase in the ambient temperature surrounding a container or other systematic failures. As noted in Chapter 3, combined gas law, an increase in temperature will result in an increase in pressure. For example, a container has 208.197 L of chemical stored in an unventilated warehouse at 14.7 psi and at 299.67 K. The temperature in the storage location increases to 312.44 K. Inserting this information into the combined gas law equation shown in Chapter 3, the pressure increased to 15.33 psi. If the container was not designed to handle this pressure, then over-pressurization can occur. The results of over-pressurization can be catastrophic, such as fires and explosions.

Other Physical Safety Hazards

Chemicals in liquid or solid states can cause employees to slip, trip, or fall. Crushing or mechanical injuries may also occur as a result of materials handling and storage. Pinch points are created by the handling and storage of drums, which can cause crushing and soft tissue injuries.

Fires and Explosions

There are many potential causes of explosions and fires associated with hazardous materials, which include the following:

- Chemical reactions that produce explosions, fires, or heat
- Ignition of explosive or flammable chemicals
- Ignition of materials caused by oxygen enrichment
- Agitation of shock- or friction-sensitive compounds
- Sudden release of materials under pressure

Explosions and fires may arise spontaneously. However, more commonly, they result from activities such as moving drums, accidentally mixing incompatible chemicals, or introducing an ignition source into an explosive or flammable environment.[3] Fires and explosions pose a threat to personnel, equipment, and facilities. When working with potentially flammable or combustible materials, always use non-sparking tools, such as brass.

Corrosion

Corrosion is the disintegration of an engineered material into its constituent atoms owing to chemical reactions with its surroundings. In the most common use of the word, this means the electrochemical oxidation of metals in reaction with an oxidant such as oxygen. The formation of an oxide of iron caused by the oxidation of the iron atoms in solid solution is a well-known example of electrochemical corrosion, commonly known as rusting. This type of damage typically produces oxide(s) or salt(s) of the original metal.

In other words, corrosion is the wearing away of metals because of a chemical reaction. Many structural alloys corrode merely from exposure to moisture in the air, but the process can be strongly affected by exposure to certain substances such as acids or bases. Corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area, more or less uniformly corroding the surface. Because corrosion is a diffusion-controlled process, it occurs on exposed surfaces.

Thermal Decomposition

Thermal decomposition refers to the by-products of incomplete combustion, such as carbon monoxide gases. Other examples include reversion of chemicals exposed to heat to the materials that were used to synthesize them.

Water-Reactive Material Hazards

Water-sensitive chemicals are chemicals that react vigorously with moisture. This reaction can result in extreme heat and can be potentially flammable, corrosive, toxic, or reactive. The most common water-sensitive chemicals include sodium, potassium, lithium metals, and aluminum alkyls. Examples of water-reactive chemicals include the following:

- Alkali metals, such as Na, Li, and K
- Alkali metal hydrides, such as LiH, CaH_2, $LiAlH_4$, and $NaBH_4$
- Alkali metal amides, such as $NaNH_2$
- Metal alkyls, such as lithium and aluminum alkyls
- Halides of nonmetals

- Inorganic acid halides
- Anhydrous metal halides
- Phosphorus pentoxide
- Calcium carbide
- Organic acid halides and anhydrides of low molecular weight

Health Hazards Associated with Hazardous Materials

As discussed in Chapter 4, chemicals can enter the human body through several routes, including inhalation, ingestion, absorption, and percutaneous and intravenous injections (refer to Chapter 4).

Preventing exposure to toxic chemicals is a primary concern when working with hazardous materials in order to prevent entry into the body. A contaminant can cause damage at the point of contact or can act systemically, causing a toxic effect at a part of the body distant from the point of initial contact.

Chemical exposures are generally divided into two major categories: acute and chronic. Symptoms resulting from acute exposures usually occur during or shortly after exposure to a sufficiently high concentration of a contaminant. The term *chronic exposure* generally refers to exposures to "low concentrations" of a contaminant over a long period. The "low concentrations" required to produce symptoms of chronic exposure depend upon the chemical, the duration of exposure, and the number of exposures.[4]

Key Regulations Governing Hazardous Materials and Hazardous Wastes

Resource Conservation and Recovery Act (1976)

The Resource Conservation and Recovery Act, enacted in 1976, is the principal Federal law in the United States governing the disposal of solid waste and hazardous waste. In 1984, Congress expanded the law with the Hazardous and Solid Waste Amendments of 1984. The amendments strengthened the law by covering small quantity generators of hazardous waste and establishing requirements for hazardous waste incinerators, as well as the closing of substandard landfills. In 1986, the law was expanded further to regulate underground storage tanks and other leaking waste storage facilities. This law regulates hazardous waste "from cradle to grave," including generation, treatment, storage, and disposal of hazardous wastes.

TABLE 27.1

EPA Categories of Hazardous Waste Generators

Type of Generator	Generation Rate (per Calendar Month), Ordinary Waste	Generation Rate (per Calendar Month), Acute Hazardous Waste	Maximum Storage Amount	Maximum Storage Time
Large quantity generator (LQG)	>1000 kg (2200 lb)	>1 kg (2.2 lb)	No limit	90 days for most wastes
Small quantity generator (SQG)	>100 kg (220 lb)	≤1 kg (2.2 lb)	≥6000 kg (13,200 lb)	180 days 270 days if the TSDF is more than 200 miles away
Conditionally exempt small quantity generator (CESQG)	≤100 kg (220 lb)	≤1 kg (2.2 lb)	≤1000 kg (2200 lb)	No limit

Hazardous Waste Generators

The US Environmental Protection Agency (EPA) classifies hazardous generators according to the amount of generated hazardous waste. Table 27.1 shows the classifications and quantities allowed.

Comprehensive Environmental Response, Compensation, and Liability Act (1980)

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, was enacted by Congress on December 11, 1980. This law created a tax on the chemical and petroleum industries and provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

CERCLA

- Established prohibitions and requirements concerning closed and abandoned hazardous waste sites
- Provided for liability of persons responsible for releases of hazardous waste at these sites
- Established a trust fund to provide for cleanup when no responsible party could be identified

The law authorizes two kinds of response actions:

- Short-term removals, where actions may be taken to address releases or threatened releases requiring prompt response.
- Long-term remedial response actions, which permanently and significantly reduce the dangers associated with releases or threats of releases of hazardous substances that are serious but not immediately life-threatening. These actions can be conducted only at sites listed on the EPA's National Priorities List (NPL).

CERCLA also enabled the revision of the National Contingency Plan (NCP). The NCP provided the guidelines and procedures needed to respond to releases and threatened releases of hazardous substances, pollutants, or contaminants. The NCP also established the NPL.[5]

Superfund Amendment and Reauthorization Act of 1986

The Superfund Amendment and Reauthorization Act (SARA) amended the CERCLA on October 17, 1986. SARA reflected EPA's experience in administering the complex Superfund program during its first 6 years and made several important changes and additions to the program.

SARA

- Stressed the importance of permanent remedies and innovative treatment technologies in cleaning up hazardous waste sites.
- Required Superfund actions to consider the standards and requirements found in other state and Federal environmental laws and regulations.
- Provided new enforcement authorities and settlement tools.
- Increased state involvement in every phase of the Superfund program.
- Increased the focus on human health problems posed by hazardous waste sites.
- Encouraged greater citizen participation in making decisions on how sites should be cleaned up.
- Increased the size of the trust fund to $8.5 billion.

SARA also required the EPA to revise the Hazard Ranking System to ensure that it accurately assessed the relative degree of risk to human health and the environment posed by uncontrolled hazardous waste sites that may be placed on the NPL.[6]

Toxic Substances Control Act (1976)

The *Toxic Substances Control Act* (TSCA) became law on October 11, 1976. The Act authorized the EPA to secure information on all new and existing chemical substances, as well as to control any of the substances that were

determined to cause unreasonable risk to public health or the environment. Congress later added additional titles to the Act, with this original part designated as Title I—Control of Hazardous Substances.[7] Other titles included Title II—Asbestos Hazard Emergency Response Act, Title III—Indoor Air Radon Abatement, and Title IV—Lead-Based Paint Exposure.

Emergency Planning and Community Right-to-Know Act (1986)

The *Emergency Planning and Community Right-to-Know Act* (EPCRA) was enacted by Congress on October 17, 1986, as an outgrowth of concern over the protection of the public from chemical emergencies and dangers. Previously, this had been covered by state and local regulatory authorities. After the catastrophic accidental release of methyl isocyanate at Union Carbide's Bhopal, India, facility in December 1984, and a later toxic release from a West Virginia chemical plant, it was evident that national public disclosure of emergency information was needed. EPCRA was enacted as a stand-alone provision, Title III, in the SARA of 1986.[7]

Federal Insecticide, Fungicide, and Rodenticide Act (1972)

Congress enacted the Federal Environmental Pesticide Control Act of 1972, which amended the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) by specifying methods and standards of control in greater detail. Subsequent amendments have clarified the duties and responsibilities of the EPA. In general, there has been a shift toward greater emphasis on minimizing risks associated with toxicity and environmental degradation, and away from pesticide efficacy issues.

Important FIFRA requirements are as follows:

- No one may sell, distribute, or use a pesticide unless it is registered by the EPA or meets a specific exemption *as described in the regulations.* Registration includes approval by the EPA of the pesticide's label, which must give detailed instructions for its safe use.
- EPA must classify each pesticide as either "general use," "restricted use," or both. General-use pesticides may be applied by anyone, but restricted-use pesticides may only be applied by certified applicators or persons working under the direct supervision of a certified applicator. Because there are only limited data for new chemicals, most pesticides are initially classified as restricted use. Applicators are certified by a state if the state operates a certification program approved by the EPA.[8]

Asbestos Hazard Emergency Response Act (1986)

In 1986, the Asbestos Hazard Emergency Response Act was signed into law as Title II of the TSCA. Additionally, the Asbestos School Hazard Abatement

Reauthorization Act (ASHARA), passed in 1990, required the accreditation of personnel working on asbestos activities in schools and public and commercial buildings.

Specifically, Asbestos-Containing Materials in Schools outlines a detailed process that ensures the safe management of all asbestos-containing building materials (ACBM) by a designated person for a local education agency (LEA).

Additionally, the AHERA, passed in 1990, required the accreditation of personnel working on asbestos activities in schools and public and commercial buildings. Specifically, the Asbestos Model Accreditation Plan (40 CFR Part 763, Appendix C) required the use of accredited inspectors, workers, supervisors, project designers, and management planners (schools only) when conducting asbestos activities at schools and public and commercial buildings.

Although asbestos is hazardous when inhaled, the risk of exposure to airborne fibers is very low. Therefore, removal of asbestos from schools is often not the best course of action. It may even create a dangerous situation when none previously existed. The EPA only requires the removal of asbestos to prevent significant public exposure during demolition or renovation. The EPA does, however, require an in-place, proactive asbestos management program for all LEAs in order to ensure that ACBM remains in good condition and is undisturbed by students, faculty, and staff.[9]

Hazard Communication Standard (29 CFR 1910.1200)

The purpose of this standard is to ensure that the hazards of all chemicals produced or imported are evaluated and that information concerning their hazards is transmitted to employers and employees. This transmittal of information is to be accomplished by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, material safety data sheets, and employee training.[10] The specifics of this standard are discussed in Chapter 2.

Classification of Hazardous Materials

The United States Department of Transportation identifies hazardous materials, specifically for transportation purposes, into nine different classifications. Table 27.2 identifies each classification.

TABLE 27.2

Department of Transportation Hazardous Materials Classification (OSU[19])

Classification Division	Hazard Name	Description	Placard
1.1	Explosive	Articles and substances having a mass explosion hazard	
1.2	Explosive	Articles and substances having a projection hazard, but not a mass explosion hazard	
1.3	Explosive	Articles and substances having a fire hazard, a minor blast hazard, or a minor projection hazard, but not a mass explosion hazard	
1.4	Explosive	Articles and substances presenting no significant hazard (explosion limited to package)	
1.5	Explosive	Very insensitive substances having a mass explosion hazard	
1.6	Explosives	Extremely insensitive articles that do not have a mass explosion hazard	
2.1	Flammable gas	Flammable gas	
2.2	Nonflammable compressed gas	Nonflammable, nontoxic, inert gas under pressure	

(*Continued*)

TABLE 27.2 (CONTINUED)

Classification Division	Hazard Name	Description	Placard
2.3	Poison gas	Toxic gas	
3	Flammable liquid	Liquid having a flash point of 141°F or less	
3	Combustible liquid	Liquid having a flash point above 141°F but less than 200°F	
4.1	Flammable solid	Flammable solid	
4.2	Spontaneously combustible	Substances liable to spontaneous combustion	
4.3	Dangerous when wet	Substances that, in contact with water, emit flammable gases	
5.1	Oxidizers	Oxidizers	
5.2	Organic peroxides	Organic peroxides	

(*Continued*)

TABLE 27.2 (CONTINUED)

Classification Division	Hazard Name	Description	Placard
6.1	Toxic substances	Toxic substances	
6.2	Infectious substances	Infectious substances	
7	Radioactive	Substances having a specific activity >70 Bq/g	
8	Corrosives	Corrosives	
9	Misc. hazardous materials	Magnetized materials, elevated temperature goods, dry ice, asbestos, environmentally hazardous substances, life-saving appliances, internal combustion engines, battery-powered equipment or vehicle, zinc dithionite, and so on	

Hazardous Waste Operations

Hazardous waste operations, and specifically cleanup operations, pose a multitude of health and safety concerns to workers and to the general public. The types of hazards associated with hazardous materials and hazardous wastes have been discussed previously in this chapter. However, cleanup operations pose special threats to the safety and health of employees. Several factors distinguish the hazardous waste site environment from other occupational situations involving hazardous substances. A key factor is the uncontrolled condition of the site. Oftentimes, cleanup operations involve abandoned or seriously degraded sites. Additional factors include the large

variety and number of substances that may be present on the site. Frequently, an accurate assessment of all chemical hazards is impossible owing to the large number of substances and the potential interactions among the substances. Many times, the identity of the substances on site is unknown, especially in the early stages of the project.

Planning and Organization

Adequate planning is the first and most critical element of hazardous waste operations. By anticipating and taking steps to prevent potential hazards to health and safety, work at a waste site can proceed with minimum risk to workers and the general public. Planning involves three aspects: developing an overall organizational structure for site operations, establishing a comprehensive work plan that considers each specific phase of the operation, and developing and implementing a site safety and health plan.[11]

Training

Employees should not enter a hazardous waste site until they have been trained to a level commensurate with their job function and responsibilities and with the degree of anticipated hazards.[12] General site workers should be trained in the following subject areas, at a minimum:

- Site safety plan
- Safe work practices
- Nature of anticipated hazards
- Handling emergencies and self-rescue
- Rules and regulations for vehicles
- Safe use of field equipment
- Handling, storage, and transportation of hazardous materials
- Employee rights and responsibilities
- Use, care, and limitations of personal protective clothing and equipment
- Safe sampling techniques

Medical Program

A medical program should be developed for each site on the basis of the specific needs, location, and potential exposures of employees at the site. The

program should be designed by an experienced occupational health physician or another qualified occupational health consultant in conjunction with the Site Safety Officer. A site medical program should include the following components:[13]

- Surveillance
- Preemployment screening
- Periodic medical examinations
- Termination examination
- Treatment
- Emergency
- Nonemergency
- Record keeping
- Program review

Site Characterization

Site characterization provides the information needed to identify site hazards and select worker protection methods. The more accurate, detailed, and comprehensive the information available about the site, the more the protective measures can be tailored to the actual hazards that workers may encounter. Site characterization proceeds in three phases:[14]

- Prior to site entry, conduct offsite characterization: gather information away from the site and conduct reconnaissance from the site perimeter.
- Next, conduct on-site surveys. During this phase, restrict site entry to reconnaissance personnel.
- Once the site has been determined safe for the commencement of other activities, perform ongoing monitoring to provide a continuous source of information about site conditions.

Air Monitoring

Airborne contaminants can present a significant threat to worker health and safety. Therefore, identification and quantification of these contaminants through air monitoring is an essential component of a health and safety program at a hazardous waste site. Reliable measurements of airborne contaminants are useful for[15]

- Selecting personal protective equipment
- Delineating areas where protection is needed

- Assessing the potential health effects of exposure
- Determining the need for specific medical monitoring

Personal Protective Equipment

Anyone entering a hazardous waste site must be protected against potential hazards. The purpose of personal protective clothing and equipment (PPE) is to shield or isolate individuals from the chemical, physical, and biologic hazards that may be encountered at a hazardous waste site. Careful selection and use of adequate PPE should protect the respiratory system, skin, eyes, face, hands, feet, head, body, and hearing.[16]

Site Control

The purpose of site control is to minimize potential contamination of workers, protect the public from the site's hazards, and prevent vandalism. Site control is especially important in emergency situations, such as overturned tractor-trailers transporting hazardous materials or wastes.

Decontamination

Decontamination is the process of removing or neutralizing contaminants that have accumulated on personnel or equipment and is critical to health and safety at hazardous waste sites. Decontamination protects workers from hazardous substances that may contaminate and eventually permeate the protective clothing, respiratory equipment, tools, vehicles, and other equipment used on site.[17]

Key Information to Remember on Hazardous Materials Management

1. A hazardous material is any solid, liquid, or gas that can harm people, other living organisms, property, or the environment.
2. A hazardous waste is defined as a "solid waste" that, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (a) pose a substantial present or potential hazard to human health or the environment or (b) cause or contribute to an increase in mortality or an increase in irreversible or incapacitating illness.
3. All matter is classified according to its physical state, which is solid, liquid, or gas.

4. The physical hazards associated with materials include engulfment, overpressurization, fires and explosions, corrosion, thermal decomposition, and other physical safety hazards.
5. Routes of entry into the body are inhalation, ingestion, absorption, and percutaneous or intravenous injection.
6. The Resource Conservation and Recovery Act regulates hazardous waste from cradle to grave, including the generation, treatment, storage, and disposal of hazardous wastes.
7. Large quantity generators (LQGs) generate >1000 kg of ordinary waste, or 1 kg of acute hazardous waste per month, and can store it for up to 90 days. There is no limit on the storage amount.
8. Small quantity generators (SQGs) generate >100 kg of ordinary waste and ≤1 kg of acute hazardous waste and can store a maximum amount of 6000 kg for up to 180 days or 270 days if the treatment, storage, and disposal facility is located more than 200 miles away.
9. Conditionally exempt small quantity generators (CESQGs) generate less than or equal to 100 kg of ordinary waste and less than or equal to 1 kg of acute hazardous waste and may store less than or equal to 1000 kg indefinitely.
10. The Comprehensive Environmental Response, Compensation, and Liability Act created a tax on the chemical and petroleum industries. CERCLA established prohibitions and requirements concerning closed and abandoned hazardous waste sites. and provided for liability of persons responsible for releases of hazardous waste at these sites. In addition, it established a trust fund to provide for cleanup when no responsible party could be identified.
11. The Toxic Substances Control Act authorized the EPA to secure information on all new and existing chemical substances, as well as to control any of the substances that were determined to cause unreasonable risk to public health or the environment.
12. The US Department of Transportation classifies hazardous materials into nine different classifications, including explosives, flammable gases, flammable liquids, flammable solids, oxidizers, toxic substances, radioactive materials, corrosives, and miscellaneous hazardous materials.
13. Hazardous waste operations pose a multitude of health and safety concerns to workers and to the general public.
14. Adequate planning is the first and most critical element of hazardous waste operations.
15. Employees should not enter a hazardous waste site until they have been trained to a level commensurate with their job function and responsibilities.

16. A medical program should be developed for each site on the basis of the specific needs, location, and potential exposures of employees at the site.
17. Site characterization provides the information needed to identify site hazards and select worker protection methods.
18. Identification and quantification of air contaminants are made through air monitoring, which is essential in selecting PPE, delineating areas where protection is needed, assessing the potential health effects of exposure, and determining the need for specific medical monitoring.
19. The purpose of site control is to minimize potential contamination of workers, protect the public from the site's hazards, and prevent vandalism.
20. Decontamination protects workers from hazardous substances that may contaminate and eventually permeate the protective clothing, respiratory equipment, tools, vehicles, and other equipment used on hazardous waste sites.

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28

Radiation Safety

In order to discuss the safety aspects of any issue, it is necessary to understand the basics of the hazard or issue. In Chapter 26, the fundamentals of both ionizing and nonionizing radiation are discussed. The chapter provides an overview of such topics as particle radiation; electromagnetic radiation; basics of radiation; biological effects of ionizing radiation; description of ionizing radiation units; types of radioactive decay; radioactive half-life; radiation control measures; personal protective equipment; and non-ionizing radiation. Calculations of radioactive decay; radiation control measures for time, distance and shielding; and near and far fields for electromagnetic radiation are discussed along with examples and solutions.

Ionizing Radiation

Ionizing radiation occurs as a result of particles or electromagnetic waves having enough energy to detach electrons from atoms or molecules, thereby causing *ionization* of the atom. Ionization is defined as the process of converting a stable atom or molecule into a charged one through the gain or loss of electrons. Ionizing radiation is produced by the natural decay of radioactive material. This occurrence depends entirely on the energy of the particles or waves and not on the number. Ionizing radiation comes from radioactive materials, X-ray tubes, and particle accelerators and is present in the natural environment. There are two ways to cause ionization: direct and indirect. Direct ionization occurs as a result of charged particle interaction with matter. Indirect ionization occurs as a result of uncharged particle interaction with matter through collision. As mentioned, ionizing radiation comes in the form of particles or electromagnetic waves.

Particle Radiation

The three types of particle radiation include

- Alpha (α)
- Beta (β)
- Neutron

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Alpha (α) Radiation

Alpha radiation is a helium nucleus that has two neutrons and two protons. It causes radiation through direct ionization. The approximate range in air is only 2 cm, as it is a highly charged particle. It will not penetrate a layer of skin and does not pose any known external radiation hazards. The major hazard associated with alpha radiation is the potential for internal damage. As the alpha particles travel through matter, they create many ions. Therefore, alpha radiation is a serious hazard to the lungs and tissues internally. An example of alpha radiation is the naturally occurring source of radon. Whenever a nuclide emits an alpha particle, a new nuclide is created with a change in atomic mass of 4 and an atomic number of 2.[1] Refer to the following example:

$$^{226}_{88}\mathrm{Ra} \qquad ^{4}_{2}\mathrm{He}^{+2} \qquad ^{222}_{86}\mathrm{Rn}$$

Beta (β) Radiation

Beta particles are excess electrons. They are formed when an atom with one excess neutron transforms the neutron into a proton and ejects the extra electron. Particles can be low or high energy emitters. Low energy emitters can be shielded by cardboard, while high energy emitters need a denser shielding material. Beta radiation results from a high-speed electron with a -1 charge overall. Beta particles cannot penetrate the body to irradiate internal organs. They can penetrate dead outer-layer skin and result in damage to live skin cells. In addition, beta particles can cause damage to the lenses of the eyes. Ingestion, inhalation, or absorption through the skin might result in internal exposure.

Neutron (n) Radiation

Since neutrons do not have a charge, they do not ionize atoms in the same way that charged particles such as protons and electrons do. Neutron radiation is an indirect ionizing radiation that consists of free neutrons. Neutrons are emitted during either spontaneous or induced nuclear fission or nuclear fusion processes and very high energy reactions.[2]

Electromagnetic Radiation

The two types of electromagnetic radiation are

- Gamma radiation
- X-rays

Gamma (γ) Radiation

Gamma (**γ**) rays are released when an atomic nucleus releases excess energy after a decay reaction. Many beta emitters also emit gamma rays. There are no pure gamma emitters. Gamma rays have no charge and are highly penetrating to tissue. The approximate range in air is 500 m. There are three ways in which gamma rays interact with matter (photoelectric effect, Compton effect, and pair production). In the photoelectric effect, a gamma photon will eject an electron and transfer all of its energy to the electron. In the Compton effect, a gamma photon ejects an electron and a gamma photon, and the gamma photon may cause further ionizations. In pair production, a gamma photon comes into the vicinity of, and without coming into contact with, a nucleus, causing an electron and positron to be created.

X-rays

X-rays are produced when an atomic nucleus stabilizes itself by absorbing an electron from an electron cloud. The properties of X-rays are the same as those for gamma rays. However, X-rays have less energy than gamma rays, typically in the 500 eV to 500 keV range.

Radiation Basics

As discussed in Chapter 4, all matter is composed of atoms, and each atom is made up of three fundamental particles *(protons, neutrons,* and *electrons).* The *proton* is a subatomic particle with an electric charge of +1 elementary charge. It is found in the nucleus of each atom, along with neutrons, but is also stable by itself and has a second identity as the hydrogen ion, H^+. The mass of a proton is considered to be 1 atomic mass unit (amu). The *neutron* is a subatomic particle with no net electric charge and a mass slightly larger than that of a proton or mathematically 1 amu. They are usually found in atomic nuclei. The *nuclei* of most atoms consist of protons and neutrons, which are collectively referred to as nucleons.[2] The number of protons in a nucleus is the atomic number and defines the type of element the atom forms. The *electron* is a subatomic particle that carries an electric charge of –1. Its mass is approximately 0.0005 amu.

An atomic mass unit is approximately equal to the mass of a proton or neutron and numerically equal to 1.66E–24 g. The mass of an electron is negligible. As discussed in Chapter 4, atoms are symbolized as follows:

$$A_{X_z}$$

where

X = the chemical symbol of the element
A = the mass number (number of protons plus number of neutrons)
Z = the atomic number (number of protons in the nucleus)

TABLE 28.1

Acute Dose (Rad) Effects

Rad	Effect
0–25	No observable effect.
25–50	Minor temporary blood changes.
50–150	Possible nausea and vomiting and reduced white blood cells.
150–300	Increased severity of the above and diarrhea, malaise, loss of appetite. Some death.
300–500	Increase severity of above and hemorrhaging, depilation. LD50 at 450–500 rad.
>500	Symptoms appear sooner. LD100 at approximately 600 rad.

Source: U.S. Department of Labor (OSHA), *Introduction to Ionizing Radiation—Lecture Outline,* http://www.osha.gov/SLTC/radiationionizing/introtoionizing/ionizinghandout.html, p. 4.[7]

Biological Effects of Ionizing Radiation

General

Biological effects are attributed to the ionization process that destroys the capacity for cell reproduction or division or causes cell mutation. The effects of one type of radiation can be reproduced by any other type. A given total dose will cause more damage if received in a shorter period. A fatal dose (600 R) causes a temperature rise of only 0.001°C and ionization of 1 atom in 100 million. See Table 28.1 below.

Acute Somatic Effects

All cells in the human body are considered somatic, with the exception of the sperm and egg cells. The effects of ionizing radiation are relatively immediate to a person acutely exposed, and the severity depends upon the dose. Death usually results from damage to bone marrow or the intestinal wall. Acute radiodermatitis is common in radiotherapy, while chronic cases occur mostly in industry. Table 26.1 shows the acute dose (rad) effects.[3]

Delayed Somatic Effects

Genetic effects on offspring of exposed persons are irreversible and nearly always harmful. The doubling dose for the mutation rate is approximately 50–80 rem. The spontaneous mutation rate is approximately 10–100 mutations per million population per generation.

Critical Organs

Organs that are generally most susceptible to radiation damage include lymphocytes, bone marrow, gastrointestinal cells, gonads, and other fast-growing

cells. The central nervous system is resistant. Many nuclides concentrate in certain organs rather than being uniformly distributed over the body, and these organs may be particularly sensitive to radiation damage.

Description of Ionizing Radiation Units

Table 28.2 provides the units used in ionizing radiation and a description of each.

Types of Radioactive Decay

As part of the natural process, radioactive materials spontaneously emit various combinations of ionizing particles (alpha and beta) and gamma or X-rays of ionizing radiation to become more stable. The first type of decay is

TABLE 28.2

Radiation Unit Description

Usage	Unit	Description
Activity	Curie (Ci)	The number of atoms disintegrating per unit of time. 1 Ci = 3.7 × 1010 disintegrations per second
Activity	Becquerel (Bq)	1 1 Bq is equivalent to one decay per second
Exposure	Roentgen (R)	A Roentgen is the amount of gamma or X-ray radiation necessary to produce 1 esu (electrostatic unit) of charge in 1 cm3 of dry air at 760 mm Hg (equivalent to 0.258 × 103 Coulombs/kg air or 5.4 × 107 MeV/g air)
Exposure	Roentgen (R)	Amount of X-ray or gamma radiation that produces ionization resulting in one electrostatic unit (esu) of charge in 1 cm3 of dry air at STP. Measured in mR/h
Dose	rad (rad)	Radiation absorbed dose 1 rad = 100 erg/g 1 rad = approximately 1 R
Biological dose	Radiation equivalent to man (rem)	• Dose equivalent • Biological effect on a person varies with different types of radiation • rem = #rads × QF • QF = quality factor • QF (X-ray, gamma, and beta radiation = 1) • QF (thermal neutrons = 3) • QF (high-speed neutrons = 10) • QF (alpha particles, energy dependent = 1–20)
Biological dose	Sievert (Sv)	1 Sv = 100 rem

Source: https://www.ncbi.nlm.nih.gov/books/NBK230653/#:~:text=rad%20The%20special%20unit%20of,of%20producing%20ionization%20in%20matter.

known as *alpha decay.* In alpha decay, the atomic mass is reduced by 4 and the protons are reduced by 2. For example, radium has an atomic mass of 226 and has 88 protons. During alpha decay, a separate helium nuclide is produced that has an atomic mass of 4 and has two protons, leaving a +2 charge. In addition, the radium now becomes radon, with an atomic mass of 222 and with 86 protons. This is represented in the formula below.

$$^{226}_{88}\text{Ra} \rightarrow \quad ^{4}_{2}\text{He}^{+2} \rightarrow \quad ^{222}_{86}\text{Rn}$$

The second type of decay is known as *beta decay.* During beta decay, there is no change in the atomic mass. However, the number of protons increase by 1. For example, the element strontium has an atomic mass of 90 and has 38 protons. During beta decay, one beta electron is added, creating yttrium, which has an atomic mass of 90 and has 39 protons. Beta decay is represented as follows from strontium:

$$^{90}_{38}\boldsymbol{Sr} \rightarrow {}^{2}{}^{-}\boldsymbol{electron} \rightarrow {}^{90}_{39}\boldsymbol{Y}$$

Calculating Radioactive Decay

Radioactive decay can be calculated using the following equation:

$$N_t = N_o e^{-\gamma(t)}$$

where

N_t = number of atoms remaining at time t
N_o = number of original atoms
γ = disintegration constant ($0.693/T_{1/2}$)
t = time of decay
$T_{1/2}$ = half-life (time in which half of the original atoms will disintegrate)

For example, Strontium-90 has an initial activity of 5050 GBq/g. What would be the activity after 14 years of decay, given that the half-life value is 29.12 years?

$$N_t = N_o e^{-\gamma(t)}$$

$$N_{14\,\text{years}} = \left(5050\,\text{GBq/g}\right) e^{-\left(\frac{0.693}{29.12\,\text{years}}\right)14\,\text{years}}$$

$$N_{14\,\text{years}} = \left(5050\,\frac{\text{GBq}}{\text{g}}\right)\left(0.7167\right)$$

$$N_{14} = 3619.06\ \text{GBq/g}$$

Therefore, after 14 years, Strontium-90 would have 71.66% of the fraction of the original activity.

Radioactive Half-Life

The half-life of a radioactive element is the time that it takes for one-half of the atoms of that substance to disintegrate into another nuclear form. These can range from fractions of a second to many billions of years. In addition, the half-life of a particular radionuclide is unique to that radionuclide, meaning that knowledge of the half-life leads to the identity of the radionuclide. Table 28.3 provides a list of half-life values for commonly encountered radionuclides.

Radiation Control Methods

There are three primary controls for external radiation. These three controls are *time*, *distance*, and *shielding*.

Time

Exposure to radiation is a function of time. Therefore, reducing the time means less exposure. The time equation, used in radiation work, is as follows:

$$\text{Dose} = D \times T$$

where
D = dose rate
T = time of exposure

For example, a radiation worker is working in an area in which the radiation measures 50 mrem/h for a period of 6 h. What is the employee's total exposure for this period?

$$\text{Dose} = 50\,\frac{\text{mrem}}{\text{h}} \times 6\,\text{h}$$

$$\text{Dose} = 30\ \text{mrem}$$

Therefore, the time of exposure to radioactive materials should be minimized as much as possible.

TABLE 28.3

List of Half-Life Values for Commonly Encountered Radionuclides (https://www.osha.gov/emergency-preparedness/radiation/radioactive-isotopes)

Element	Symbol	Half-Life Value
Actinium	Ac-225	10.0 days
	Ac-227	21.773 years
	Ac-228	6.13 h
Americium	Am-241	432.2 years
	Am-242	16.02 h
	Am-242m	152 years
	Am-243	7380 years
Antimony	Sb-124	60.2 days
	Sb-125	2.77 years
	Sb-126	12.4 days
	Sb-126m	19.0 min
	Sb-127	3.85 days
Argon	Ar-41	1.827 h
Beryllium	Be-10	1.6E6 years
	Be-7	53.44 days
Cadmium	Cd-113m	13.6 years
	Cd-115m	44.6 days
Cerium	Ce-141	32.5 days
	Ce-143	33.0 h
	Ce-144	284.3 days
Californium	Cf-252	2.638 years
Carbon	C-11	20.38 min
	C-14	5730 years
Cesium	Cs-134	2.062 years
	Cs-134m	2.90 h
	Cs-135	2.3E6 years
	Cs-136	13.1 days
	Cs-137	30.0 years
	Cs-138	32.2 min
Chromium	Cr-51	27.704 days
Cobalt	Co-56	78.76 days
	Co-57	270.9 days
	Co-58	70.8 days
	Co-60	5.27 years
Copper	Cu-61	3.408 h
	Cu-64	12.701 h
Curium	Cm-242	162.8 days
	Cm-243	28.5 years
	Cm-244	18.11 years
	Cm-245	8500 years
	Cm-246	4730 years
	Cm-247	1.56E7 years
	Cm-248	3.39E5 years

(*Continued*)

TABLE 28.3 (CONTINUED)

List of Half-Life Values for Commonly Encountered Radionuclides (https://www.osha.gov/emergency-preparedness/radiation/radioactive-isotopes)

Element	Symbol	Half-Life Value
Iridium	Ir-192	74.02 days
Krypton	Kr-83m	1.83 h
	Kr-85	10.72 years
	Kr-85m	4.48 h
	Kr-87	76.3 min
	Kr-88	2.84 min
Plutonium	Pu-238	87.74 years
	Pu-239	24,065 years
	Pu-240	6537 years
	Pu-241	14.4 years
	Pu-242	3.76E5 years
	Pu-243	4.956 h
	Pu-244	8.26E6 years
Radium	Ra-223	11.434 days
	Ra-224	3.66 days
	Ra-225	14.8 days
	Ra-226	1600 years
	Ra-228	5.74 years
Radon	Rn-219	3.96 s
	Rn-220	55.6 s
	Rn-222	3.824 days
Selenium	Se-75	119.78 days
	Se-79	65,000 years
Strontium	Sr-85	64.84 days
	Sr-87m	2.81 h
	Sr-89	50.5 days
	Sr-90	29.12 years
	Sr-91	9.5 h
	Sr-92	2.71 h
Thallium	Tl-201	73.06 h
	Tl-207	4.77 min
	Tl-208	3.07 min
	Tl-209	2.20 min
Uranium	U-232	72 years
	U-233	1.59E5 years
	U-234	2.445E5 years
	U-235	7.03E8 years
	U-236	2.34E7 years
	U-237	6.75 days
	U-238	4.47E9 years
	U-240	14.1 h

(*Continued*)

TABLE 28.3 (CONTINUED)

List of Half-Life Values for Commonly Encountered Radionuclides (https://www.osha.gov/emergency-preparedness/radiation/radioactive-isotopes)

Element	Symbol	Half-Life Value
Yttrium	Y-90	64.0 h
	Y-91	58.51 days
	Y-91m	49.71 min
	Y-92	3.54 h
	Y-93	10.1 h

Distance

The dose received by employees is inversely proportional to distance; therefore, the greater the distance from the source means the less the dose. The maximum distance from the source to properly control or manipulate the materials should be determined. To calculate the dose at a distance, use the following equation, known as the Inverse Square Law:

$$I_2 = I_1 \frac{(d_1)^2}{(d_2)^2}$$

where
I_1= intensity at distance 1
I_2= intensity at distance 2
$d_{1 \text{ or } 2}$ = distances at location 1 or 2

For example, an employee is working approximately 1 ft from the source, which measures 148 mrem/h. If the employee were to work 3 ft from the source, what would the dose rate be?

$$I_2 = 148\,\text{mrem/h}\,\frac{(1\,\text{ft})^2}{(3\,\text{ft})^2}$$

$$I_2 = 148\,\text{mrem/h}\,\frac{1}{9}$$

$$I_2 = 16.44\ \text{mrem/h}$$

By moving the employee an additional 2 ft from the source, the exposure would be 16.44 mrem/h versus 148 mrem/h.

Source Strength for Gamma (γ) Radiation

To calculate the source strength from gamma (γ) radiation, use the following equation:

$$S = 6CE$$

where
S = R/h/1 ft
C = Curie strength
E = energy (MeV)

Shielding

By placing an appropriate shield between the radioactive source and the employee, radiation is attenuated, and exposure may be completely eliminated or reduced to an acceptable level. The type and amount of shielding needed to achieve a safe working level vary with the type and quantity of radioactive material used. The half-value layer (HVL) may be used as a guide to the thickness of the shielding necessary to block the radiation. The HVL is the thickness of the shielding necessary to reduce the radiation dose rate to half of the original or unshielded dose rate. The HVL is expressed in units of distance (millimeters or centimeters). The HVL is inversely proportional to the attenuation coefficient. The *attenuation coefficient* is a quantity that characterizes how easily a material or medium can be penetrated by a beam of light, sound, particles, or other energy or matter.[4] The HVL can be calculated using the following equation:

$$\text{HVL} = \frac{0.693}{\mu}$$

where
μ = the linear absorption coefficient for the material.
Table 28.4 shows an example of HVL for various sources.
To calculate the approximate effectiveness of a shield, use one of the following equations:

TABLE 28.4

Example of Half-Value Thickness (mm)

			Source		
Material	**Co 60**	**Ir 192**	**Yb 169**	**100 kV X-rays**	**250 kV X-rays**
Depleted uranium	6.5	2			
Lead	12.4	6.4	2.6	0.24	0.82
Steel	20	13	9.5	6.3	10
Concrete	66	48		19	28

Source: Online Showcase, 2010. http://onlineshowcase.tafensw.edu.au/ndt/content/rad_safety/task4/accessible.htm#topic5.[5]

For gamma or X-rays,

$$I = I_o e^{-\mu x}$$

where
I = intensity after shielding
I_o = original intensity
μ = the linear absorption coefficient of material
x = shield thickness

For example, the intensity at 2 ft from the ^{137}Cs source is 35 mrem/h. What is the intensity at this point if a 5-cm lead shield is placed between the source and the detector? (μ for lead [662 keV gamma ray] = 1.23 cm^{-1})

$$I = \left(35 \frac{\text{mrem}}{\text{h}}\right) e^{-1.23 \times 5}$$

$$I = \left(35 \frac{\text{mrem}}{\text{h}}\right)(0.002)$$

$$I = 0.07 \text{mrem / h}$$

Beta (β) particle radiation is somewhat more complex, in that it is more strongly affected by shielding since they have charge and mass. Therefore, for beta (β) radiation, use the following equation:

$$I = \beta I_o e^{-\mu x}$$

where
I = intensity after shielding
I_o = original intensity
μ = the linear absorption coefficient of material
x = shield thickness
β = radiation scatter "buildup" factor (for radiation workers, the Occupational Safety and Health Administration [OSHA] assumes $\beta = 1$)

Note: Buildup factors can be located in American Nuclear Standard 6.4.3. Using a β of 1 would not make a difference in this calculation.

Personal Protective Equipment

The specific type of protective equipment used depends on the nuclide, level of activity, chemical form, and type of work being performed. Examples of personal protective equipment may include laboratory coats, safety glasses, respirators, or specially designed radiation protection suits. Other equipment may include biological safety cabinets and specially designed ventilation systems.

OSHA Exposure Standards

OSHA standards for ionizing radiation can be found in 29 CFR 1910.1096. Table 28.5 summarizes the exposure limits for ionizing radiation.

Non-ionizing Radiation

Nonionizing radiation is described as a series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light. Nonionizing radiation includes the spectrum of ultraviolet (UV), visible light, infrared (IR), microwave (MW), radio frequency (RF), and extremely low frequency (ELF). Lasers commonly operate in the UV, visible, and IR frequencies. Nonionizing radiation is found in a wide range of occupational

TABLE 28.5

Occupational Ionizing Radiation Exposure Limits

Body Part	rem
Whole body; head and trunk; active blood-forming organs; lens of eye; or gonads	1 1/4 rem/quarter
Hands and forearms; feet and ankles	18 3/4 rem/quarter
Skin of whole body	7 1/2 rem/quarter
Whole body	5 rem/year

Note: $D = 5(N - 18)$, where D = dose; N = age of employee on last birthday. The dose to the whole body, when added to the accumulated occupational dose to the whole body, shall not exceed $5(N - 18)$ rem, where N is equal to the individual's age in years at his last birthday.

Source: https://www.osha.gov/ionizing-radiation/standards#:~:text=Whole%20body%3A%20head%20and%20trunk,body%3A%207.5%20rem%20per%20quarter. [6]

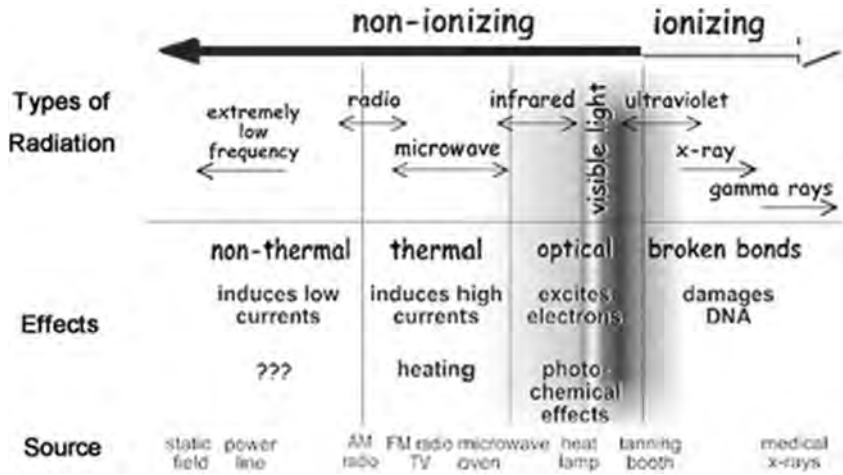


FIGURE 28.1
Types of radiation in the electromagnetic spectrum (Source: From U.S. Environmental Protection Agency (EPA), https://19january2017snapshot.epa.gov/radiation/radiation-basics_.html).

settings and can pose a considerable health risk to potentially exposed workers if not properly controlled.[6]

Nonionizing radiation is illustrated in Figure 28.1

UV Radiation

UV radiation energy waves are a range of electromagnetic waves 100 to 400 nm long (between the x-ray and visible light spectrums). The division of UV radiation may be classified as Vacuum UV (100–200 nm), UV-C (200–280 nm), UV-B (280–315 nm), and UV-A (315–400 nm).[8] UV radiation has a high photon energy range and is particularly hazardous because there are usually no immediate symptoms of excess exposure. Sources of UV radiation include the sun, black light, welding arcs, and UV lasers.[6] The effects of UV radiation are primarily limited to the skin and eyes. UV radiation can cause redness or erythema, photosensitization, skin cancer, corneal lesions, photokeratitis (welder's flash), or snow blindness from welder's flash. The controls for UV radiation include solid materials to block the sun and sunscreen applied to the exposed areas.

Visible Light Radiation

The different visible frequencies of the electromagnetic spectrum are "seen" by our eyes as different colors. Good lighting is conducive to increased production and may help prevent incidents related to poor lighting conditions. Excessive visible radiation can damage the eyes and skin.[6] Control measures for visible light include enclosures or filters.

IR Radiation

The skin and eyes absorb IR radiation as heat. Workers normally notice excessive exposure through heat sensation and pain. Sources of IR radiation include furnaces, heat lamps, and IR lasers.[6] Sources of IR radiation include thermal sources such as furnaces, welding, lasers, and incandescent bulbs. Infrared A (0.74–2.5 nm) can penetrate the skin and eyes to the retina. Infrared B (2.5–5 nm) is almost completely absorbed by the upper layers of the skin and eyes. Infrared C (5–300 nm) can cause thermal burns on the skin and cornea and cataracts on the lens. Control measures for IR radiation are enclosures and glass doped without neodymium is opaque to near-IR shielding.

MW Radiation

MW sources include ovens, televisions, and some radars. The effects of MWs include a rise in surface temperature, and longer wavelengths can penetrate and heat deep body tissue, causing cataracts on the lens of the eyes. Shielding with metals that have a high dielectric constant and are transparent is the method to control MW radiation.

Certain behavior characteristics of electromagnetic fields dominate at one distance from the radiating antenna, while a completely different behavior can dominate at another location. Electrical engineers define boundary regions to categorize behavior characteristics of electromagnetic fields as a function of distance from the radiating source. These regions are the "near field," "transition zone," and "far field," as illustrated in Figure 28.2.[8]

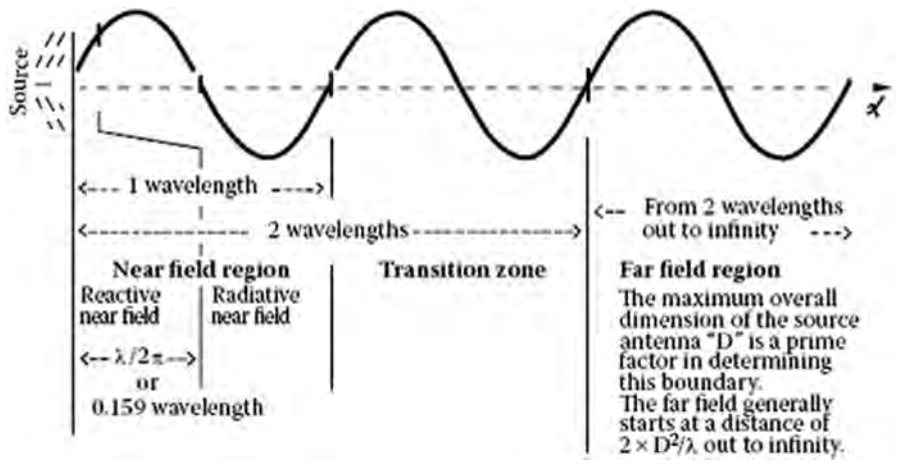


FIGURE 28.2
Diagram of electromagnetic field zones (Source: From EPA.[8]).

Calculating MW Radiation (Near Field)

The region located less than one wavelength from the source is called the "near field." Here, the relationship between E and H becomes very complex, and it requires measurement of both E and H to determine the power density. Also, unlike the far field where electromagnetic waves are usually characterized by a single polarization type (horizontal, vertical, circular, or elliptical), all four polarization types can be present in the near field.[8]

To calculate the estimated power density levels in the near field of large aperture circular antennas, use the following equation:

$$W = \frac{16P}{\pi D^2} = \frac{4P}{A}$$

where

W = power density (mW/cm^2)
P = antenna power (W)
A = effective antenna area (cm^2)
D = diameter of antenna (cm)

Example

Calculate the estimated power density at a diameter of 36 in. (1 in. = 2.54 cm) for 50 W transmitted through an antenna (1 W = 1000 mW).

The first step would be to convert inches into centimeters; 36 in. = 91.44 cm. Now, we can proceed to the following equation:

$$W = \frac{16(50{,}000\ \text{mW})}{(3.14)(91.44\ \text{cm})^2}$$

$$W = \frac{800{,}000\ \text{mW}}{26{,}254.4\ \text{cm}^2}$$

$$W = 30.5\ \text{mW} / \text{cm}^2$$

Calculating MW Radiation (Far Field)

To calculate the estimated power density levels in the far field of large aperture circular antennas, use the following equation:

$$W = \frac{GP}{4\pi r^2} = \frac{AP}{\lambda^2 r^2}$$

where

W = power density (mW/cm^2)
P = antenna power (mW)
A = effective antenna area (cm^2)
λ = wavelength (cm)
r = distance from antenna (cm)

$G = \text{gain}\left(\text{calculated by } G = \frac{4\pi A}{\lambda^2}\right)$. When gain is used in calculations, the values of the absolute gain must be used: $G = 10^{\frac{g}{10}} = \text{antilog}\frac{g}{10}$.

Example

Calculate the estimated power density at 150 ft for 10,000 W transmitted through an antenna with a gain of 10. Remember to convert watts into milliwatts and feet into centimeters.

$$W = \frac{GP}{4\pi r^2}$$

$$W = \frac{(10)(10\,\text{mW})}{4(3.14)(4572\,\text{cm}}$$

$$W = \frac{100{,}000{,}000\ \text{mW}}{(4)(3.14)(20{,}903{,}184\ \text{cm}}$$

$$W = \frac{100{,}000{,}000\ \text{mW}}{262{,}677{,}157.2\ \text{cm}}$$

$$W = 0.38\text{mW / cm}$$

RF Radiation

RF radiation sources include communication systems, heat sealers, medical equipment, radar, and MW ovens. RFs can cause deep body heating, cataracts, reproductive effects, immune system effects, and endocrine effects. RFs are controlled by enclosures and shielding.

Lasers

LASER is an acronym that stands for *light amplification by stimulated emission of radiation*. It is a mechanism for emitting electromagnetic radiation, usually light or visible light, through stimulated emission. Laser output may be continuous or pulsed. Lasers are used in everyday life, including electronics, information technology, military, medicine, and law enforcement. Lasers are classified into four categories on the basis of their ability to cause injury. Table 28.6 illustrates the four classes of lasers.

TABLE 28.6

Laser Classification

Classification	Description
Class I	Low power and low risk.
Class II	Visual system, low power, and low risk. The blinking reflex is typically sufficient to protect employees. However, if staring into the laser is done, retinal damage can occur.
Class III	Medium power and medium risk.
Class IIIA	Limit the exposure to the eyes, visible laser.
Class IIIB	Can cause accidental injury if viewed directly.
Class IV	High power and high risk. There is a concern with specular reflected beams.

Laser Safety-Control Measures

The general control measures for lasers include the following:

- Shielding to reflect radiation
- Shielding to absorb radiation
- Restrict access to the radiation source
- Increase distance from the source
- Limit the time of exposure
- Utilize less hazardous radiation

Effective Irradiance

Effective irradiance is the measurement of some radiometers used to measure actinic UV. Effective irradiance is measured in W/cm^{2}nm. To calculate the effective irradiance of an instrument, use the following equation:

$$E_{\text{eff}} = \sum E_\lambda S_\lambda \Delta_\lambda$$

where

E_{eff} = effective irradiance (W/cm^2·nm)
E_λ = spectral irradiance (W/cm^2·nm)
S_λ = relative spectral effectiveness (no unit)
Δ_λ = bandwidth (nm)

Optical density can be calculated using the following equation:

$$\text{OD} = \log\left[\frac{I_{\text{incident}}}{I_{\text{transmitted}}}\right]$$

where

OD = the measured optical density of the material being evaluated (dimensionless)

$I_{incident}$ = incident laser beam intensity (W/cm^2)

$I_{transmitted}$ = transmitted laser beam intensity (W/cm^2)

Example

Given a laser having a spectral irradiance of 4 W/cm^2-nm, a relative spectral effectiveness of 1, and a bandwidth of 5.9 nm. What is the effective irradiance?

$$E_{eff} = \mathring{a}\left(4\frac{W}{cm^2}nm\right)(1)(5.9\ nm)$$

$$E_{eff} = \quad W / cm^2n$$

Speed of Light Equation

To calculate the speed of light, use the following equation:

$$C = \lambda f = \frac{\lambda}{T}$$

where

C = the speed of light in a vacuum, which is 2.99792458×10^8 m/s

λ = the wavelength of the photon (m)

f = the frequency associated with the photon (cycles/s)

Key Information to Remember on Radiation Safety

1. Ionizing radiation occurs as a result of particles or electromagnetic waves having enough energy to detach electrons from atoms or molecules, thereby causing ionization of the atom.
2. The three types of particle radiation are alpha (α), beta (β), and neutron (n).
3. Alpha radiation is a helium nucleus that has two neutrons and two protons.
4. Beta particles are excess electrons. They are formed when an atom with one excess neutron transforms the neutron into a proton and ejects the extra electron.

5. Neutron radiation is an indirect ionizing radiation that consists of free neutrons.
6. The two types of electromagnetic radiation are gamma (γ) radiation and x-rays.
7. Gamma rays are released when an atomic nucleus releases excess energy after a decay reaction.
8. X-rays are produced when an atomic nucleus stabilizes itself by absorbing an electron from an electron cloud.
9. Biological effects of ionizing radiation are attributed to the ionization process that destroys the capacity for cell reproduction or causes cell mutation.
10. Radioactive decay occurs as alpha decay, beta decay, or a series chain.
11. The radiological half-life is the time it takes for one-half of the atoms of that substance to disintegrate into another nuclear form.
12. The three primary controls for radiation are time, distance, and shielding.
13. Reducing the time means less exposure.
14. The dose received by employees is inversely proportional to distance; therefore, the greater the distance from the source means the less the dose.
15. By placing an appropriate shield between the radioactive source and the employee, radiation is attenuated, and exposure may be completely eliminated or reduced to an acceptable level.
16. OSHA's ionizing radiation exposure limit is 5 rem/year, 1.25 rem/quarter.
17. Nonionizing radiation is described as a series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light. Nonionizing radiation includes UV, visible light, IR, MW, RF, and ELF.

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29

Walking and Working Surfaces

Work-related falls represented 15.8% (865 fatalities) of all fatalities (5,486) in 2022, according to the United States Bureau of Labor and Statistics. Of the work-related fall fatalities, 2.6% (144) were the result of falls to the same level. The remaining 13.1% (721) were the result of falls to a lower level. In addition to the fatalities, slips, trips, and falls are the cause of numerous work-related injuries. Slip hazards such as grease, oil, water, ice, snow, liquid spills, or polished floors contribute greatly to work-related injuries. Obstacles in the walkways, such as hoses, cords, or open file cabinets present a greater risk of a trip, which could also result in a serious injury or fatality. Because of the seriousness of falls, OSHA has issued final rules in Subpart D, which includes the following standards:

- 29 CFR 1910.21: Definitions
- 29 CFR 1910.22: General Requirements
- 29 CFR 1910.23: Ladders
- 29 CFR 1910.24: Step Bolts and Manhole Steps
- 29 CFR 1910.25: Stairways
- 29 CFR 1910.26: Dockboards
- 29 CFR 1910.27: Scaffolds and Rope Descent Systems
- 29 CFR 1910.28: Duty to Have Fall Protection and Falling Object Protection
- 29 CFR 1910.29: Fall Protection Systems and Falling Object Protection-Criteria and Practices
- 29 CFR 1910.30: Training Requirements

These standards and hazards will be discussed throughout this chapter, along with some recommended control measures.

Definitions

Because the definitions for walking and working surfaces are provided as a standard, a discussion of them is not required in this section. Therefore, the

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definitions relating to Subpart D are provided, as a courtesy, in the Glossary section at the end of this chapter.

General Requirements

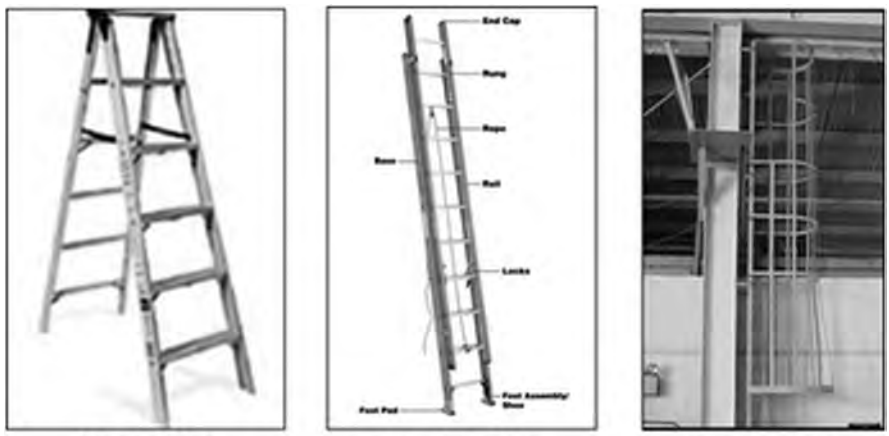
As with any OSHA standard, there are general requirements. The general requirements state that the burden is on employers to ensure that walking and working surfaces are properly maintained and kept in a clean, orderly, and sanitary condition. If the area is a dry area, it must be periodically swept and kept free of obstacles. If the area is a wet area, such as a food processing facility where water is regularly sprayed, adequate drainage and sloping must be in place. All working surfaces should be designed to handle the intended maximum loads. Safe access and egress to an area must always be provided and maintained. Finally, the general requirements are that the employer inspects and maintain walking and working surfaces in a safe condition. If the repairs cannot be made immediately safe, then the hazard must be guarded to prevent employees from using them until repaired.[1]

Ladders

Ladders are one of the most common and useful tools in manufacturing, construction, heavy industry, or in general industry facilities. They also represent a significant hazard to employees if not maintained or used in a safe condition and manner. This section will provide information on the types, uses, specific hazards, and preventive measures recommended to control the hazards and reduce the potential for injury or fatality. Generally, the employer must ensure that the ladder rungs, steps, and cleats are parallel, level, and uniformly spaced when the ladder is in use. In addition, the employer must ensure that the ladders are maintained in proper working condition, inspected before each use, and taken out of service when they do not meet the acceptable standards outlined in 29 CFR 1910.23.

Types

There are varying types of ladders including step ladders, extension ladders, fixed ladders, and portable platform ladders. Each of these is discussed below. Photograph 29.1 is provided to illustrate the various types of ladders discussed in this chapter.



PHOTOGRAPH 29.1
Types of ladders.[1]

Step Ladders

As defined in the glossary at the end of this chapter, a ***stepladder*** means a self-supporting, portable ladder that has a fixed height, flat steps, and a hinged back. They are constructed of wood, metal, or fiberglass. To begin the discussion on stepladders, it is first necessary to look at the basics of a stepladder. Photograph 29.2 illustrates the various parts associated with stepladders.

Extension Ladders

Extension ladder means a non-self-supporting portable ladder that is adjustable in length. Extension ladders are very useful when reaching elevated heights and are typically used in exterior environments to reach roofs or interior areas to reach platforms where stepladders are not appropriate. Figure 29.1 illustrates the maximum angle of the extension ladder by using the following equation:

$$\text{Base of Ladder Distance from Wall (ft)} = \frac{x}{4}$$

where

x = Height of the wall to the landing point.

Example

The height of the wall to the landing point of the ladder is 12 ft. Determine the distance of the base of the ladder from the base of the wall.



PHOTOGRAPH 29.2
Stepladder parts (Source: Yates, W. David 2019).

$$\text{Base of Ladder Distance from Wall (ft)} = \frac{12}{4}$$

= 3 ft.

The base of the ladder should be 3 ft from the base of the wall. The length of the ladder from the ground to the landing point can be calculated using the Pythagorean theorem.

$a^2 + b^2 = c^2$

a = height of wall from ground to landing point (in this case it is 12 ft)

b = distance of the ladder base from the base of the wall (in this case, it is 3 ft)

$12^2 + 3^2 = c^2$

144 sq. ft + 9 sq. ft = c^2

153 sq. ft = c^2

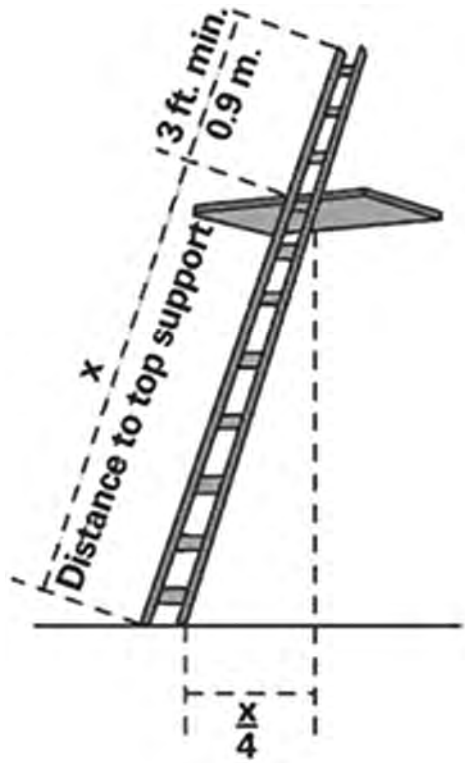


FIGURE 29.1
Extension ladder angles and requirements beyond landing point.[1]

$$\sqrt{153\,\text{sq.ft}} = \sqrt{c}$$

12.4 ft = c

It is important that the length of c be known, as an additional 3 ft needs to be added to it to extend the 3 ft beyond the landing point, shown below.

Fixed Ladders

Fixed ladder means a ladder with rails or individual rungs that are permanently attached to a structure, building, or equipment. Fixed ladders include individual-rung ladders but not ship stairs, step bolts, or manhole steps.[2] OSHA has established the following guidelines regarding fixed ladders:

- Fixed ladders must be capable of handling their intended load.
- Grab bars do not protrude on the climbing side beyond the rungs of the ladder that they serve.

- Siderails of through or sidestep ladders extend 42 in. above the top of the access level or landing platform.
- A cage around the fixed ladder is required when the fixed ladder is 20 ft or greater in length. The cage must begin at 7 ft.
- Other details are listed in 29 CFR 1910.23.

Ladder Basics

An important aspect for any operator to understand is the duty rating of a ladder. This rating is based on the total weight of the user, tools, and other equipment. Photograph 29.3 is an example showing the duty rating of a ladder. One of the requirements for ladders, in general, is that the labels be maintained in a legible manner at all times. This information is usually located on the rails of the ladder. This ladder is considered a medium-duty ladder with a total capacity of 225 lb, meaning that the total weight the ladder will support is 225 lb. Table 29.1 describes the duty ratings of ladders.

While every user of a ladder should be trained on the various classifications/ratings, it is equally important for the safety professional to be aware of this requirement as well. Oftentimes, the safety professional will be required to conduct the training. In addition, a question or two on stepladders has been known to present itself on the ASP/CSP examinations.

Example
An employee weighs 156 lb. Her tool pouch weighs approximately 15 lb. In addition, she is assisting another mechanic who is on another stepladder to maneuver a 40 lb motor in place. It occasionally may rest with its full weight on the top of the stepladder. Would the ladder identified in Photograph 29.3 be adequate for this task (based on the rating)?

Answer: Yes. The maximum combined weight is 211 lb. The maximum load capacity of this ladder is 225 lbs and is designated as a Medium Duty stepladder.

Other information contained on the label (Photograph 29.3) is that the ladder is a 6′ ladder, with a maximum reach height of 10′. The maximum reach height is based on a 5′6″ person with a vertical 12″ reach and the highest

TABLE 29.1

Ladder Duty Ratings[3]

Type	Duty Rating	Load Capacity
Type IAA	Special duty	375 lb
Type IA	Extra heavy duty	300 lb
Type I	Heavy duty	250 lb
Type II	Medium duty	225 lb
Type III	Light duty	200 lb



PHOTOGRAPH 29.3
Example of a ladder duty rating (Source: Yates, W. David 2019).

standing level of 3'10". The label will also indicate the model number of the ladder, along with the manufacturer. Normally, located on the side rails or steps, there will be specific warning labels, such as the ones shown in Photographs 29.4 and 29.5.

The materials used to construct ladders each have their advantages and disadvantages. For example, a wooden ladder is often used when there are electrical conductivity concerns. There are significant disadvantages to using a wooden ladder. Some of the disadvantages are that they are heavier to carry, creating ergonomic issues for the user, and the wood is subject to damage much more readily than the others. It is not weather resistant and is subject to rotting. Fiberglass is one of the better materials used to construct step ladders. It is lighter than wood, has good material strength, and is weather resistant. It is also used when electrical conductivity is an issue. The major disadvantage to using ladders constructed of fiberglass is that it is subject to chipping and structural damage if not properly stored. Finally, aluminum ladders are probably the lightest to transport, have good overall material strength, and is also weather resistant. The major disadvantage of using a ladder constructed of aluminum is in the electrical conductivity properties of aluminum.



PHOTOGRAPH 29.4
Step warning label (Source: Yates, W. David, 2019).



PHOTOGRAPH 29.5
Side rail warning label (Source: Yates, W. David, 2019).

Common Causes of Ladder Accidents

In order to prevent injuries involving ladders, it is critical for employees, supervisors, managers, and safety professionals to understand the reasons and causes of previous accidents. A study of ladders over the years has revealed that the most common causes include (a) overreaching while working on the ladders; (b) ladders not being securely placed or placed on unstable surfaces; (c) climbing ladders using only one hand; (d) carrying equipment or tools while climbing the ladders; (e) exceeding the capacity of the ladders, such as weight or standing on the top rung; (f) using damaged ladders; and (g) leaving tools or equipment on the ladders that fall.

Prevention of Ladder Accidents

Ladder Inspections

It is common sense (or should be) that every ladder should be inspected by the operator prior to use. What is not always common sense is that employers must have a ladder safety program to prevent injuries to employees. While not specifically spelled out in 29 CFR 1910.23, it is highly recommended and strongly encouraged that a company have a written ladder safety program that requires a formal inspection of ladders quarterly or, at a minimum, annually, by a competent person. The following items should be checked to ensure that the ladder is in good working order:

- Steps (loose, cracked, bent or missing)
- Rails (cracked, loose, frayed, split)
- Labels (Present and legible)
- Top Shelf (Loose, bent, missing or broken)
- Spreaders (present, loose, bent, or broken)
- General ladder condition (rotting wood, workable parts, rust, etc.)
- Bracings (present and secure; not loose)
- Shoes (Present and secure, not loose)
- Rivets (present and secure, not loose)

If any of the above are not in good working order, the ladder should be removed from service.

Proper Ladder Usage

A review of the accident causes above shows that the overwhelming majority of accidents are generally caused by improper usage of the ladders. Therefore, a discussion on proper usage is necessary at this point. The first step in using a ladder has already been described above, and that is to first

conduct an inspection on the ladder to ensure that it is physically in good working condition. A user of a ladder must follow the safety precautions listed below to prevent injuries.

- When climbing or descending a ladder, it is vital that the user uses both hands and faces the ladders. Three points of contact are always required when ascending or descending a ladder.
- NEVER use the top two steps of a ladder.
- Follow the "belt buckle" rule, which states that the user's body/torso should be kept between the side rails to prevent overreaching and potential falls.
- Place warning signs and barriers around areas where ladders are used.
- Avoid placing a ladder in a doorway. If placing a ladder in a doorway is unavoidable, the door should be secured to prevent it from opening. Another option is to use another employee who is dedicated to preventing the opening and closing of doors.
- For stepladders, it is advisable to have a second person hold and secure the ladder.
- Tools must be carried in a tool pouch worn on the user's person, but not carried in the hands. An alternative is to use a rope to retrieve the tool pouch/bucket once the place of work has been reached.
- NEVER work on a ladder that is closer than 10 ft to an energized power line.
- BEFORE using the ladder, make sure that it is placed on a firm, secure foundation that is level.
- NEVER exceed the weight capacity of the ladder.

Step Bolts and Manhole Bolts

In the 2017 revisions of OSHA's Walking and Working Surfaces Standards, each step bolt installed on or after January 17, 2017, in an environment where corrosion may occur must be constructed of, or coated with, materials that protect against corrosion. Furthermore, these bolts must be designed, constructed, and maintained to prevent the employee's foot from slipping off the end of the step bolt. They must be uniformly spaced at vertical distances of not less than 12 in. Furthermore, they should not be more than 18 in. apart, measured from center to center. However, the spacing from the entry and exit surface to the first step bolt may differ from the spacing between the

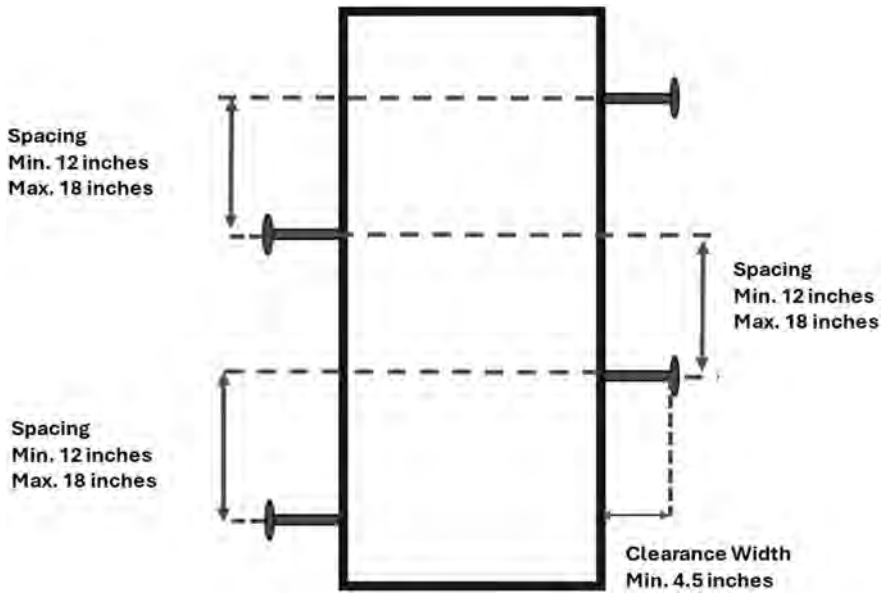


FIGURE 29.2
Step bolt spacing requirements[4] (Source: Yates, W. David, 2019).

other step bolts. Step bolts must be at least 4.5 in. to accommodate the footing of the user.

Figure 29.2 illustrates the spacing requirements for the step bolts. Manhole steps must be spaced 16 in. apart and have a minimum width of 10 in. to provide adequate stepping space. An additional requirement for manhole steps is that they must be constructed of corrugated or dimpled materials to prevent slipping. Both step bolts and manhole steps must be designed to hold the intended weight.

Stairways

The safety requirements established by OSHA are listed in 29 CFR 1910.25 (Stairways). Handrails, stair rail systems, and guardrail systems are listed in 29 CFR 1910.28. Most of the load-bearing equipment and devices that have been discussed so far require that the device be designed to carry the intended load. Stairs, on the other hand, must be designed to support five times the normal anticipated load. Before proceeding, it is necessary to understand the terminology regarding stairs. Figure 29.3 describes the various components of stairs.

The minimum vertical distance between any stair tread and the overhead is 6 ft, 8 in. The stair risers and tread distances must be uniform throughout.

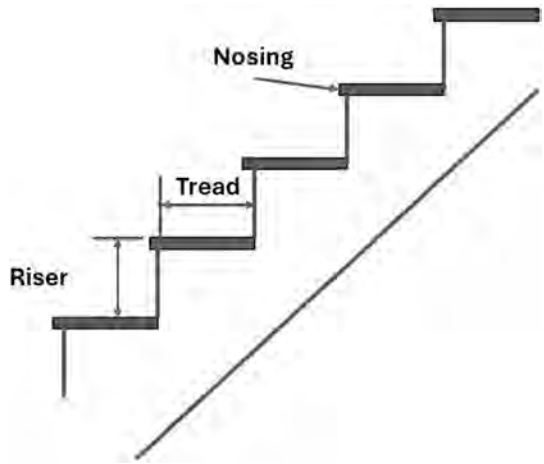


FIGURE 29.3
Stair components[5] (Source: Image Yates, W. David (2019).

Table 29.1 provides the stairway rise and tread dimensions. Stairway landings must be at least 30 in. in depth and must be at least as wide as the width of the stairs. Stairs are installed at angles between 30 and 50 degrees, have a maximum riser height of 9.5 in, and have a minimum width of 22 in. Spiral staircases, however, should have a minimum width of 26 in. Minimum stair tread depths are 7.5 in.

In addition to the minimum and maximum requirements listed in Table 29.2 , stair treads should be constructed of slip-resistant materials. Handrails are required when there are at least three treads and four risers. The requirements for handrails are listed in Table 29.3 .

TABLE 29.2

Stairway Rise and Tread Dimensions[5]

Angle to Horizontal	Rise (in Inches)	Tread run (in Inches)
30° 35′	6½	11
32° 08′	6¾	10¾
33° 41′	7	10½
35° 16′	7¼	10¼
36° 52′	7½	10
38° 29′	7¾	9¾
40° 08′	8	9½
41° 44′	8¼	9¼
43° 22′	8½	9
45° 00′	8¾	8¾
46° 38′	9	8½
48° 16′	9¼	8¼
49° 54′	9½	8

TABLE 29.3

Handrail Requirements[6]

Stair Width	Enclosed	One Open Side	Two Open Sides	With Earth Built up on Both Sides
<44 in.	At least one handrail	One stair rail system with handrail on open side.	One stair rail system on each open side	
44–88 in.	One handrail on each enclosed side	One stair rail system with handrail on open side and one handrail on enclosed side.	One stair rail system with handrail on each open side.	
>88 in.	One handrail on each enclosed side and one immediate handrail located in the middle of the stair.	One stair rail system with handrail on the enclosed side, and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on each open side and one immediate handrail located in the middle of the stair.	
Exterior stairs <44 in.				One handrail on at least one side

Figure 29.4 is an illustration of handrail requirements for stairs in an enclosed stairway.

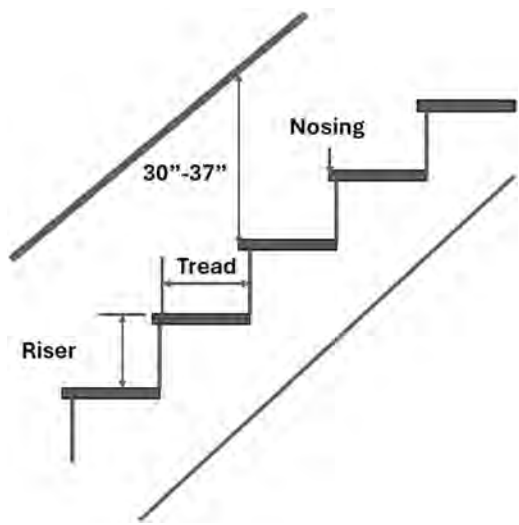


FIGURE 29.4
Stair handrail requirements[5] (Source: Yates, W. David 2019).

Dockboards

Dockboards are used to transition from one area to another, where there may be a slight level difference or a condition that may create a gap between structures. An example of an area where a dockboard may be required is from a warehouse dock to the inside of a semi-trailer. The user must ensure that the dockboard is designed to support the intended load requirement. In addition, the user should ensure that the dockboard is placed securely to prevent slipping or creeping due to the back-and-forth transportation of materials into and out of the semi-trailer. This can be accomplished by anchoring them in place or using equipment or devices that prevent the dockboard from moving out of a safe position. When entering or exiting a semi-trailer using a powered industrial truck or other mechanical vehicle, it is advisable to also ensure that the semi-trailer wheels have been chocked and the driver informed to not attempt to move until told to do so. Furthermore, there should be an edge of sufficient height to ensure that the vehicle does not travel beyond the edge of the dockboard. Dockboard requirements are also discussed in Chapter 28, under Materials Handling and Storage. In this chapter, the design and physical requirements are discussed. These requirements are listed in 29 CFR 1910.28 (Duty to Have Fall Protection). The following requirements regarding dockboards are:[5]

- Employer must ensure that each employee on a dockboard is protected from falling 4 ft or more to a lower level by a guardrail system or handrails.
- Dockboards are being used solely for material-handling operations using motorized equipment.
- Employees engaged in these operations are not exposed to fall hazards greater than 10 ft.
- Employees have been trained in accordance with 29 CFR 1910.30.

Scaffolds and Rope Descent Systems

Scaffold means any temporary elevated or suspended platform and its supporting structure, including anchorage points, used to support employees, equipment, materials, and other items. For purposes of this subpart, a scaffold does not include a crane-suspended or derrick-suspended personnel platform or a rope descent system.[2]

Scaffold accidents represent a significant amount of injuries in both General and Construction Industries according to BLS statistics in recent years. The major causes of scaffolding injuries include the following:

- Failure of scaffold supports or planking
- Damaged or defective equipment
- Improper construction of scaffolds
- Slips, trips, and falls while on the scaffold
- Improper or inadequate training
- Falling objects striking either a worker on or below the scaffold

There are some basic requirements for scaffold construction that must be adhered to at all times. The first is that all erection, movement, dismantling, or altering of a scaffold must be under the direct supervision of a "competent person." A "competent person" defined by OSHA is someone who is capable of identifying existing and predictable hazards in the surrounding or working conditions, which are unsanitary, hazardous to employees, and who has authorization to take prompt corrective measures to eliminate them.[6]

There are several different types of scaffolds, including tubular scaffolds, suspended scaffolds, and special scaffolds. The most common type used is the tubular scaffold, which is discussed in the following section.

Tubular Scaffolds

Tube and coupler scaffolding is so named, because of the construction and assembly methods. Figure 29.5 is an illustration of a tube and coupler scaffold. They are constructed of tubes that are coupled together with connectors. When properly constructed, they are used whenever a heavy load is anticipated. Transverse bracing, which forms an "X," is required on the ends of the scaffolds and at least at every third set of posts horizontally and every fourth runner vertically. Building ties must be installed at the bearer levels between the transverse bracing. On straight-run scaffolds, longitudinal bracing across the inner and outer rows of posts must be installed diagonally on both ends and extend upward from the base of the end posts to the top of the scaffold at approximately a 45° angle. Whenever the length of a scaffold is greater than its height, longitudinal bracing must be repeated beginning at least every fifth post. When the length is less than the height, the longitudinal bracing should be installed from the base of the end posts upward to the opposite end posts and then in alternating directions until reaching the top of the scaffold.

Planking

Planking is usually constructed of wood or metal. Regardless of the type, the planking must be able to support its own weight and at least four times the



FIGURE 29.5
Tube and coupler scaffolding.

intended load. Each platform must be planked and decked as fully as possible, with the space between the platform and uprights not more than 1 in. wide. The space must not exceed 9 ½ in. when side brackets or odd-shaped structures result in a wider opening between the platform and the uprights. Deflection of the planking should not exceed 1/60th of the span when loaded. The scaffold platform and walkway must be at least 18 in. wide, and guardrails and/or personal fall arrest systems must be used. Solid sawn wood, fabricated planks, and fabricated platforms may be used as scaffold planks. Table 29.4 shows the maximum permissible spans, rated load capacity, and nominal thicknesses to be used. Planking is to extend at least 6 in. beyond the cross support member and should not exceed 12 in. beyond the end of a cross support member.

TABLE 29.4

Maximum Permissible Spans, Rated Load Capacity, and Nominal Thickness[7]

Maximum intended nominal load (psf)	Maximum permissible span using full thickness undressed lumber (ft)	Maximum permissible span using nominal thickness lumber (ft)
25	10	8
50	8	6
75	6	

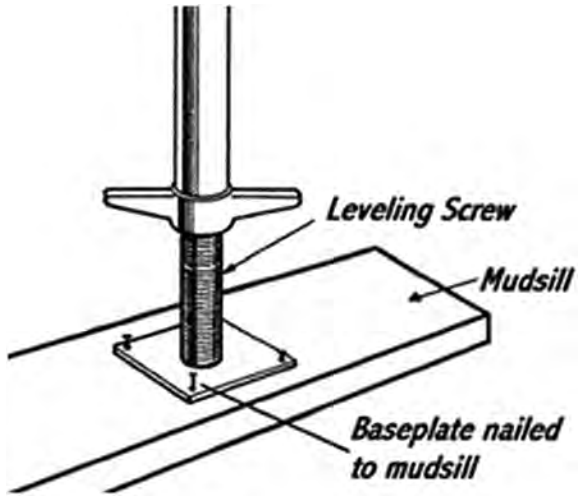


FIGURE 29.6
Illustration of mud sills and base plate.[9]

Footing and Foundation

The footings and foundations of any structure, especially scaffolds, are critical to its stability. Supported scaffold's poles, legs, posts, frames, and uprights must bear on base plates and mud sills or other adequate firm foundation. It is extremely important that the supporting members be prevented from sinking into the ground or otherwise becoming unleveled. Figure 29.6 provides an illustration of base plates and mud sills.

Electrical Hazards

It is no secret that scaffolding constructed of metal, which is the majority of scaffolds, and energized electricity is a poor combination. Table 29.5 shows

TABLE 29.5

Require Clearance Distances between Scaffolding and Power Lines[8]

	Insulated Lines
<300 V	3 ft
300 V to 50 kV	10 ft
>50 kV	10 ft plus 4 in. for each additional kV
Uninsulated Lines	
Up to 50 kV	10 ft
>50 kV	10 ft plus 4 in. for each additional kV

the required clearance distances between scaffolds and electrical power lines.

Other Common Scaffolding Hazards

In addition to the aforementioned hazards, the following hazards must also be considered regarding the use of scaffolds:

- Work around energized electrical systems. Distances may be found in 29 CFR 1926.451(f)(6)
- Fall protection requirements
- Falling object hazards from above the platform
- Safe access and egress
- Lighting in the area
- Energized equipment and wiring in the immediate vicinity of the scaffolding
- Mud sills and base plates are properly installed
- Level scaffolding
- Open areas exceeding 18 in. maximum
- Toeboards in place

Use of Scaffolds

Before scaffolds are used, they must be inspected. This inspection is required daily and must be conducted by a competent person. This inspection must be documented. Usually, there is an inspection tag located at the entrance/ladder of the scaffold. If there are any discrepancies noted during the inspection, they must be corrected prior to use. Each employee using a scaffold must be trained in the safe use and operation of the scaffold, along with the procedures to control or mitigate the hazards.

Rope Descent Systems

As defined by OSHA, a ***rope*** descent system means a suspension system that allows an employee to descend in a controlled manner and, as needed, stop

at any point during the descent. A rope descent system usually consists of a roof anchorage, support rope, a descent device, carabiner(s) or shackle(s), and a chair (seatboard). A rope descent system is also is called controlled descent equipment or apparatus. Rope descent systems do not include industrial rope access systems.[8] Just like scaffolding, rope descent systems (RDS) should be assembled and constructed under the direct supervision of a trained and competent person. The RDS must also be frequently inspected. This inspection is required at least daily by the competent person. The competent person will inspect the rigging, anchors, tiebacks, counterweight, hooks, and the overall structural integrity of the system. Rigging should not be an improvised or makeshift affair. There should be engineered and permanent anchor points that have been certified initially and at least every 10 years by a competent person. A professional engineer is not required.

Duty to Have Fall Protection and Falling Object Protection

Simply put, OSHA places the requirement or duty to have fall protection squarely on the shoulders of the employer. 29 CFR 1910.28 requires that employers provide protection for each employee exposed to fall and falling object hazards. The only exceptions to the rule are inspections, investigations, or assessments. The exception does not apply, however, when there are fall protection systems in place that can be utilized during these activities. When fall protection systems are required, they must be constructed, installed, and maintained in accordance with the requirements established in 29 CFR 1910.29. One thing that must be clear in terms of the requirement to have fall protection is that under the General Industry Standards, the fall protection requirement must begin at heights of 4 ft and under the Construction Industry Standards at 6 ft.

Falling Object Protection

Scaffolds, like other working platforms, are required to have falling object protection installed. Specific means of preventing falling objects from becoming a hazard include installing toeboards, screens, debris nets, catch platforms, canopy structures, or barricades.[9] Guardrails must be between 38 and 45 in. for the top rail. In addition, the scaffolding guardrail must also have a mid-rail. In addition to the physical guards to prevent falling, employees working near or around the scaffolding should be required to wear hard hats.

Fall Protection Systems and Falling Object Protection—Criteria and Practices

Before discussing the requirements of fall protection, it is a good idea to understand what happens in a fall. No one gets up and goes to work in the morning thinking, "I'll just take a fall off of a scaffold today." In fact, many employees probably do not think about it at all or think they will have time to grab onto something in order to stop the fall. The truth is that it takes about one-third of a second to become aware that one is falling and another one-third of a second for the body to react. A body in free fall (gravity) will fall at a rate of 32 ft per second. Given the fact that the body will react only after two-thirds of a second, the falling employee will have fallen at least 21 ft.

Calculating Velocity, Time, and Distance of a Fall

In this section, it is understood that the calculations and equations used are for free-falling objects only. They do not apply when an object or body is under additional power or force, other than gravity. When calculating the rate of a fall, there are four basic equations that can be used. Collectively, these equations are referred to as the "Kinematic Equations." The Kinematic Equations are used to calculate the displacement, velocity, time, and/or acceleration of an object or body.

$$d = v_i t + \frac{1}{2} a t^2$$

$$v_f = v_i + at$$

$$v_f^2 = v_i^2 + 2ad$$

$$d = \frac{v_i + v_f}{2} t$$

where

d = displacement (distance; usually expressed in meters or feet)

t = time (usually expressed in seconds)

a = acceleration (speed; usually expressed in meters or feet per second, but could be miles or kilometers per hour)

v_f = final velocity

An object or body in free fall will accelerate at 9.8 m/s² or 32 f/s/s. One point to remember is that when an object falls downward due to gravity, the distance is expressed in negative (–) numbers. For example, if a rock falls from a cliff 27 m, it would be expressed as –27 m. The opposite applies if something were projected upward or horizontally; the value would be expressed in positive (+) numbers.

Example 27.1

An operator was walking beneath a catwalk, where there was a missing toeboard, when the maintenance technician dropped his wrench striking the operator on his head. The operator was wearing the required hard hat while working in this area. The height at the point where the wrench was dropped was 5.5 m above the height of the operator's head (point of impact). The initial velocity at the point of being dropped was 0.0 m/s.

A. *How much time was required from the point the object was dropped to the point of impact?*

To solve this, you would look at the known variables that you have, which are the distance (5.5 m), the initial velocity which is 0.0 m/s, and the rate of acceleration due to gravity (9.8 m/s²—because other variables are expressed in meters). Therefore, we can select the following equation to solve for *t*:

$$d = v_i t + \frac{1}{2} a t^2$$

$$= -5.5\,m = 0.0\,\frac{m}{s}(t) + \frac{1}{2}\left(\frac{-9.8\,\frac{m}{s}}{s}\right) t^2$$

$$= -5.5\,m = -4.9\,m/s^2 t^2$$

$$= \frac{-5.5\,m}{-4.9\,ms^2} = \frac{-4.9m}{s^2} t^2$$

$$= 1.12\,s^2 = t^2$$

$$t = 1.06 \text{ seconds}$$

Example 27.2

An operator was walking beneath a catwalk, where there was a missing toeboard, when the maintenance technician dropped his wrench striking the operator on his head. The operator was wearing the required hard hat while working in this

area. The height at the point where the wrench was dropped was 5.5 m above the height of the operator's head (point of impact). The initial velocity at the point of being dropped was 0.0 m/s.

B. *What is the final velocity of the wrench upon impact to the operator's head/hard hat?*

Use the following equation to solve for the final velocity:

$$v_f = v_i + at$$

$$v_f = -\frac{0.0\,m}{s^2} + -\frac{9.8\,m}{s^2} 1.06\,sec$$

$$v_f = -\frac{9.8\,m}{s^2} 1.06\,sec$$

$$v_f = 10.39\,m/sec$$

One can use these equations to calculate either the time, distance, or speed of a fall, depending on the information known.

Fall Protection and Prevention

There are huge differences between fall protection and fall prevention. Fall protection consists of systems and equipment that are used once a fall has actually occurred. Fall prevention involves procedures, equipment, and systems utilized to ensure that a fall never occurs. It is obvious that fall prevention is the preferred choice of the two. Fall protection systems include such equipment as body harnesses, anchor points, connectors, lanyards, deceleration devices, and safety nets. Fall prevention systems may include equipment such as handrails, guardrails, ladder cages. Specific requirements for fall protection and arrest systems are found in 29 CFR 1910.29.

Fall Arrest Systems

All fall arrest systems must be designed to prevent the person involved in a fall from hitting the next lower level. When calculating the requirements, the distances must include the following:

- Height of the person
- Lanyard length
- Length of the deceleration device (shock absorbance)

Example

An employee has a height of 6 ft. He is working on the second level of a building. The height of the second level of the building to the ground is 12 ft. The employee is wearing a body harness with a 6-ft lanyard equipped with a 3.5-ft shock absorbing device on the lanyard. Is this adequate fall arrest protection to prevent the employee from hitting the ground in the event of a fall?

$$\text{Total distance} = \sum EH + LL + DD + 3$$

where
EH = Employee height (feet)
LL = Lanyard length (feet)
DD = Deceleration device length (feet)
Note: 3′ is added as a Safety Factor.

$$\text{Total distance} = \sum 6' + 6' + 3.5' + 3'$$

$$\text{Total distance} = 18.5'$$

As shown in the above example, the employee will hit the ground using a 6′ lanyard with a shock-absorbing deceleration device. Anchor points for fall arrest systems must be rated for 5,000 lb per person using the anchor point.

Training Requirements

Regardless of the requirements of OSHA to train employees on the construction, assembly, and use of fall hazards, it just makes good common sense to do so. Training is critical to preventing any work-related hazards. With that being said, OSHA requirements must be strictly adhered to. OSHA requires that before an employee is exposed to a fall hazard, the employer must provide training. Training must be conducted by a qualified person. ***Qualified*** describes a person who, by possession of a recognized degree, certificate, or professional standing, or by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter, the work, or the project.[8] Training must consist, at a minimum, of the following topics:

- Nature of fall hazards
- Procedures to be followed to minimize the hazards
- Correct procedures for installing, inspecting, operating, maintaining, and disassembling the personal fall arrest systems (PFAS)
- Correct use of PFAS

Key Information to Remember on Walking and Working Surfaces

1. The employer must ensure that ladders are maintained in proper working condition, inspected before each use, and taken out of service when they do not meet the requirements of 29 CFR 1910.23.
2. Extension ladders should extend at least 3 ft beyond the landing point.
3. Extension ladders must follow a 1:4 ratio from the base of the ladder to the base of the wall. In other words, to calculate the distance from the base of the wall to the base of the ladder, use the following equation: $Distance = \frac{x}{4}$, where x is the height of the wall.
4. Ladder ratings are based on their maximum weight capacities.
5. Stair treads and risers should be uniform.
6. Stair treads should also be constructed of slip-resistant materials.
7. Scaffolding should be placed on level and solid foundations.
8. Fall protection is required at 4′ under the general industry standards and at 6′ under the construction industry standards.
9. Personal Fall Arrest Systems (PFAS) include the harness, connecting devices, lanyard, and anchor points that must be rated to withstand 5,000 lb of force per person.
10. Employees must be trained before they are permitted to be exposed to fall hazards.

Glossary

The definitions applying to subpart D (29 CFR 1910.21 through 29 CFR 1910.30) are as follows:

Alternating tread-type stair means a type of stairway consisting of a series of treads that usually are attached to a center support in an alternating manner such that an employee typically does not have both feet on the same level while using the stairway.

Anchorage means a secure point of attachment for equipment such as lifelines, lanyards, deceleration devices, and rope descent systems.

Authorized means an employee whom the employer assigns to perform a specific type of duty or allows in a specific location or area.

Cage means an enclosure mounted on the side rails of a fixed ladder or fastened to a structure behind the fixed ladder that is designed to surround the climbing space of the ladder. A cage is also is called a "cage guard" or "basket guard."

Carrier means the track of a ladder safety system that consists of a flexible cable or rigid rail attached to the fixed ladder or immediately adjacent to it.

Combination ladder means a portable ladder that can be used as a stepladder, extension ladder, trestle ladder, or stairway ladder. The components of a combination ladder also may be used separately as a single ladder.

Dangerous equipment means equipment such as vats, tanks, electrical equipment, machinery, equipment or machinery with protruding parts, or other similar units that, because of their function or form, may harm an employee who falls into or onto the equipment.

Designated area means a distinct portion of a walking-working surface delineated by a warning line in which employees may perform work without additional fall protection.

Dockboard means a portable or fixed device that spans a gap or compensates for a difference in elevation between a loading platform and a transport vehicle. Dockboards include, but are not limited to, bridge plates, dock plates, and dock levelers.

Equivalent means alternative designs, equipment, materials, or methods that the employer can demonstrate will provide an equal or greater degree of safety for employees compared to the designs, equipment, materials, or methods specified in this subpart.

Extension ladder means a non-self-supporting portable ladder that is adjustable in length.

Failure means a load refusal, breakage, or separation of component parts. A load refusal is the point at which the ultimate strength of a component or object is exceeded.

Fall hazard means any condition on a walking-working surface that exposes an employee to a risk of harm from a fall on the same level or to a lower level.

Fall protection means any equipment, device, or system that prevents an employee from falling from an elevation or mitigates the effects of such a fall.

Fixed ladder means a ladder with rails or individual rungs that is permanently attached to a structure, building, or equipment. Fixed ladders include individual-rung ladders but not ship stairs, step bolts, or manhole steps.

Grab bar means an individual horizontal or vertical handhold installed to provide access above the height of the ladder.

Guardrail system means a barrier erected along an unprotected or exposed side, edge, or other area of a walking–working surface to prevent employees from falling to a lower level.

Handrail means a rail used to provide employees with a handhold for support.

Hoist area means any elevated access opening to a walking–working surface through which equipment or materials are loaded or received.

Hole means a gap or open space in a floor, roof, horizontal walking-working surface, or similar surface that is at least 2 in. (5 cm) in its smallest dimension.

Individual-rung ladder means a ladder that has rungs individually attached to a building or structure. An individual-rung ladder does not include manhole steps.

Ladder means a device with rungs, steps, or cleats used to gain access to a different elevation.

Ladder safety system means a system designed to eliminate or reduce the possibility of falling from a ladder. A ladder safety system usually consists of a carrier, safety sleeve, lanyard, connectors, and body harness. Cages and wells are not ladder safety systems.

Low-slope roof means a roof that has a slope less than or equal to a ratio of 4 in 12 (vertical to horizontal).

Lower level means a surface or area to which an employee could fall. Such surfaces or areas include, but are not limited to, ground levels, floors, roofs, ramps, runways, excavations, pits, tanks, materials, water, equipment, and similar surfaces and structures, or portions thereof.

Manhole steps mean steps that are individually attached to, or set into, the wall of a manhole structure.

Maximum intended load means the total load (weight and force) of all employees, equipment, vehicles, tools, materials, and other loads the employer reasonably anticipates being applied to a walking–working surface at any one time.

Mobile means manually propelled or movable.

Mobile ladder stand (ladder stand) means a mobile, fixed-height, self-supporting ladder that usually consists of wheels or casters on a rigid base and steps leading to a top step. A mobile ladder stand also may have handrails and is designed for use by one employee at a time.

Mobile ladder stand platform means a mobile, fixed-height, self-supporting unit having one or more standing platforms that are provided with means of access or egress.

Open riser means the gap or space between the treads of stairways that do not have upright or inclined members (risers).

Opening means a gap or open space in a wall, partition, vertical walking-working surface, or similar surface that is at least 30 in. (76 cm) high and at least 18 in. (46 cm) wide, through which an employee can fall to a lower level.

Personal fall arrest system means a system used to arrest an employee in a fall from a walking-working surface. It consists of a body harness, anchorage, and connector. The means of connection may include a lanyard, deceleration device, lifeline, or a suitable combination of these.

Personal fall protection system means a system (including all components) an employer uses to provide protection from falling or to safely arrest an employee's fall if one occurs. Examples of personal fall protection systems include personal fall arrest systems, positioning systems, and travel restraint systems.

Platform means a walking-working surface that is elevated above the surrounding area.

Portable ladder means a ladder that can readily be moved or carried and usually consists of side rails joined at intervals by steps, rungs, or cleats.

Positioning system (work-positioning system) means a system of equipment and connectors that, when used with a body harness or body belt, allows an employee to be supported on an elevated vertical surface, such as a wall or windowsill, and work with both hands free. Positioning systems are also are called "positioning system devices" and "work-positioning equipment."

Qualified describes a person who, by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter, the work, or the project.

Ramp means an inclined walking–working surface used to access another level.

Riser means the upright (vertical) or inclined member of a stair that is located at the back of a stair tread or platform and connects close to the front edge of the next higher tread, platform, or landing.

Rope descent system means a suspension system that allows an employee to descend in a controlled manner and, as needed, stop at any point during the descent. A rope descent system usually consists of a roof anchorage, support rope, a descent device, carabiner(s) or shackle(s), and a chair (seatboard). A rope descent system is also

is called controlled descent equipment or apparatus. Rope descent systems do not include industrial rope access systems.

Rung, step, or cleat means the crosspiece of a ladder on which an employee steps to climb up and down.

Runway means an elevated walking-working surface, such as a catwalk, a footwalk along shafting, or an elevated walkway between buildings.

Scaffold means any temporary elevated or suspended platform and its supporting structure, including anchorage points, used to support employees, equipment, materials, and other items. For purposes of this subpart, a scaffold does not include a crane-suspended or derrick-suspended personnel platform or a rope descent system.

Ship stair (ship ladder) means a stairway that is equipped with treads, stair rails, and open risers, and has a slope that is between 50 and 70 degrees from the horizontal.

Side-step ladder means a type of fixed ladder that requires an employee to step sideways from it in order to reach a walking-working surface, such as a landing.

Spiral stairs are a series of treads attached to a vertical pole in a winding fashion, usually within a cylindrical space.

Stair rail or stair rail system means a barrier erected along the exposed or open side of stairways to prevent employees from falling to a lower level.

Stairway (stairs) means risers and treads that connect one level with another and include any landings and platforms in between those levels. Stairways include standard, spiral, alternating tread-type, and ship stairs.

Standard stairs mean fixed or permanently installed stairways. Ship, spiral, and alternating tread-type stairs are not considered standard stairs.

Step bolt (pole step) means a bolt or rung attached at intervals along a structural member used for foot placement and as a handhold when climbing or standing.

Stepladder means a self-supporting, portable ladder that has a fixed height, flat steps, and a hinged back.

Stepstool means a self-supporting, portable ladder that has flat steps and side rails. For purposes of the final rule, a stepstool includes only those ladders that have a fixed height, do not have a pail shelf, and do not exceed 32 in. (81 cm) in overall height to the top cap, although side rails may extend above the top cap. A stepstool is designed so an employee can climb and stand on all the steps and the top cap.

Through ladder means a type of fixed ladder that allows the employee to step through the side rails at the top of the ladder to reach a walking-working surface, such as a landing.

Tieback means an attachment between an anchorage (e.g., structural member) and a supporting device (e.g., parapet clamp or cornice hook).

Toeboard means a low protective barrier that is designed to prevent materials, tools, and equipment from falling to a lower level and protect employees from falling.

Travel restraint system means a combination of an anchorage, anchorage connector, lanyard (or other means of connection), and body support that an employer uses to eliminate the possibility of an employee going over the edge of a walking-working surface.

Tread means a horizontal member of a stair or stairway but does not include landings or platforms.

Unprotected sides and edges mean any side or edge of a walking-working surface (except at entrances and other points of access) where there is no wall, guardrail system, or stair rail system to protect an employee from falling to a lower level.

Walking–working surface means any horizontal or vertical surface on or through which an employee walks, works, or gains access to a work area or workplace location.

Warning line means a barrier erected to warn employees that they are approaching an unprotected side or edge, and designates an area in which work may take place without the use of other means of fall protection.

Well means a permanent, complete enclosure around a fixed ladder.

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30

Materials Handling and Storage

A review of workers' compensation claims, in any given year or any given state, will reveal approximately the same statistics. The most common injuries reported include slips, trips, and falls (16%); being struck by or against objects (10%); and material handling, which represents approximately 32% of all work-related injuries. The remaining percentage includes injuries from other categories. This chapter will list and discuss the various aspects of material handling.

As with any topic, it is first necessary to understand the basics. It is important to understand exactly what "materials handling" is. Materials handling involves moving goods short distances, usually within a specified area, as well as storing and controlling products because of the manufacturing process. Materials handling, especially in terms of this chapter, is further divided into two categories: (1) manual materials handling and (2) equipment-assisted materials handling.

Manual materials handling (MMH) is defined as moving or handling things by lifting, lowering, pushing, pulling, carrying, holding, or restraining. MMH is also the most common cause of occupational fatigue, low back pain, and lower back injuries.[1] (CCOHS) Materials handling by mechanical means involves the use of equipment such as 55-gal drum trucks (dolly), powered industrial trucks, or other automated devices.

Regardless of the method used, materials handling is a major source of workplace injuries. In many operations, materials handling can involve packing product boxes, palletizing them, and using a forklift for their transport or storage. In other operations, massive movement of large containers, such as shipping containers, may be required, making the methods far more complicated. When considering the problems associated with manual materials handling, one typically thinks of ergonomic injuries that can result. However, other injuries include lacerations, amputations, crushing injuries, and fractures. This chapter will delve into various issues such as the problems, methods, equipment, and lift devices used for materials handling.

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Issues and Hazards Related to Material Handling

The issue of work-related injuries has already been discussed. To clarify the fact that approximately 32% of all workers' compensation cases result from materials handling, this section will break down the causes of those injuries further. By understanding the causes, preventive measures can be implemented early in the process. Injuries are the result of either an unsafe condition or an unsafe act. Unsafe conditions causing injuries in the materials handling process include such conditions as holes in the flooring or grating, uneven flooring, slipping and tripping hazards, and in many cases, obstructed paths of travel. Unsafe behaviors may include improper lifting techniques, awkward lifting positions, lifting loads that are too heavy for a single person, or lifting loads that are too large.

One of the major functions of any safety organization or production supervisor is to conduct a comprehensive job hazard analysis (JHA) of the processes. A review of many workers' compensation injuries related to materials handling shows that most tasks or processes that result in such injuries are poorly designed. When designing a task, operation, or process involving materials handling, there are several aspects or questions that should be considered. Below are just a few of the questions that should be reviewed:

- What are the individual steps to complete a task?
- Condition of flooring or travel ways
- Are there slip, trip, or fall hazards present?
- Is there unnecessary bending and twisting?
- Does the lift exceed the recommended weight limits (RWLs) using the NIOSH Lifting Index?
- Can a manual lift be eliminated altogether?
- Are there thermal conditions, such as cold storage warehouses, that create hazards in addition to the routine material handling hazards?

Using this information, a job hazard analysis should be performed to identify and eliminate hazards associated with materials handling tasks. Other hazards/conditions that should be evaluated in the JHA include:

- Weight of container or product
- Size of container or product
- Sharp edges
- Grip
- Temperature of product
- Respiratory hazards (i.e., dust, fibers, etc.)

- Hazardous materials
- Secure loading
- Movement (motion of loading-swing motion)
- Visibility

Lifting Techniques

As mentioned earlier in this chapter, some of the most common injuries resulting from manual materials handling are back and leg injuries. One thing that is certain in a materials handling operation is that manual lifting cannot be eliminated entirely. Somewhere along the line, manual lifting will be required, even if the manual lifting occurs on the receiving end. For this reason, it is necessary and important to discuss the various lifting techniques in some detail. Before beginning the discussion on the individual techniques, an understanding of general lifting principles will be helpful.

General Lifting Guidelines

When manual lifting must be done in a materials handling operation, there are some guiding principles associated with lifting that should be considered in order to eliminate any potential injuries. These principles are listed below.[2]

- Reduce the weight of the load or packages
- When heavy loads cannot be reduced or broken down into smaller loads, then assistance with the lift should be obtained
- Lifting with the legs
- Keep the back straight
- Avoid twisting during the lift
- Avoid overhead lifting

Individual Lifting Procedures

Basic Lifting Technique (also Known as the Diagonal Lift)[3]

When performing an individual manual lift, it is extremely important to follow these guidelines to ensure that a back or other muscle injury does not occur. The first guideline to follow is the same for any task to be performed, and that is to conduct a hazard assessment before the operation begins. The hazard assessment should include an evaluation of the size, weight, and shape of the part or packaging. Determine if the lift requires assistance or



FIGURE 30.1
Basic lifting (diagonal lift) technique[3] (Source: McNeel, Johnny 2024).

is necessary in the first place. Evaluate the conditions between the point of origin and the point of destination. Make sure that there are no obstructions in the path of travel. The basic lifting technique is shown in Figure 30.1.

Before making the lift, the lifter should ensure that the load is balanced and that a good grip on the object can be maintained throughout the lift. The lifter should bend at the knees, keeping the back straight throughout the lift. Grip the container or product securely. The arms and hands should be as close to the body as possible during the lift. As mentioned previously, there should be clear visibility between the point of origin and the point of destination. Twisting and bending during the lift should be kept to a minimum. Instead of twisting, the lifter should pivot the feet. At the point of destination, the lifter will bend the knees and lower the load using the reverse procedure described above.

Team Lifting Procedure and Technique

At first thought, a two-person lift is better than an individual lift and can significantly reduce potential injuries. However, two-person lifts come with their own hazards that must be eliminated before the lift occurs. For example, if the lift is performed by individuals of different heights, the balance of the load is shifted to the shorter person, creating more stress on that individual. To avoid this, it is important that the persons be of similar heights. As in the individual lift procedure, a job hazard analysis (JHA) should also be performed on a team lift. One person should be designated as the team lead, who is responsible for directing the move. Both individuals should bend the knees at the same time, keeping their backs straight. Once a firm grip has been secured, the team lead should direct the lift to begin, which should be conducted in a smooth motion. While traveling, the team's movement should be smooth, and the load maintained in a level position. When traveling up or down stairs, it is strongly recommended that the taller of the two people be



FIGURE 30.2
Half-knee lifting technique (Source: McNeel, Johnny 2024).

on the lower level of the lift. This will help to balance the load and ensure it is maintained in a level position.

Half-Kneeling Technique

The half-knee position is used for light to moderate loads. To perform this lift, the lifter will go down on one knee while maintaining a neutral spine position. The lifter will get as close to the object as possible, secure the object with a firm grip, and using the leg in the 90° angle position raise the load to a standing position. This technique is demonstrated in Figure 30.2.

Tripod Lift Technique[3]

The tripod lift technique is used to lift materials that have a slightly uneven weight imbalance or a load that may shift during the lifting or traveling process. It is also recommended for those with limited or decreased arm strength. It is not, however, recommended for personnel with bad knees.[3]

When performing this lift, the lifter will place one of their feet next to the object to be lifted. Keeping the back straight and the buttocks out, the lifter will lower themselves down onto one knee. The object to be lifted should be adjacent to the knee that is on the ground. The object should be grasped firmly with both hands. The object is then slid from the ground to mid-thigh of the leg with the knee on the ground. While keeping the head forward and the back straight, the object is then transferred to the thigh of the opposite leg. Both forearms are then placed beneath the object with the palms of the hands in an upward position. The arms and hands are then brought to the chest, hugging the load. The load is then lifted by pushing upward with the legs. This technique is illustrated in Photograph 30.3.

Power-Lifting Technique[3]

This lift is a variation of the Basic Lifting Technique described above. The power-lifting technique can be seen in Figure 30.3.



PHOTOGRAPH 30.1
Tripod grip technique[4] (Source: McNeel, Johnny 2024).



FIGURE 30.3
Power-lifting technique[3] (Source: McNeel, Johnny 2024)..

The power-lifting technique differs from the basic lifting technique in that the legs are spread wide when bending at the knees. A wide stance is taken when bending, while keeping the back straight and the buttocks out, the legs and hips are used to lower the body to the actual lift position. Once in the lift position, the lifter places a firm grasp on the object or container to be lifted. The legs and hips are then used to raise the load, which is kept close to the body. The arms are also kept as close to the body as possible. As in the basic lifting technique, twisting should be avoided. This is accomplished through the pivoting of the feet. If conducted properly, the knees are bent to roughly a 120° angle.

Golfer's Lift[3]

The Golfer's Lift technique is most often used to pick up smaller light objects. The lift is performed by placing the hand on a fixed surface to steady the

lifter. Keeping the back straight, the lifter will extend one leg out while at the same time leaning down to pick up the object. The leg is extended to serve as a counterbalance. The object or container is then grasped firmly. While lifting, the extended leg is then dropped at the same time as the upper body comes to the standing position. This technique is demonstrated in Figure 28.4 .

Partial Squat Technique[3]

The partial squat technique is commonly used to lift small light objects with handles that are at or near knee height. To perform this lift, the lifter will stand beside the object to be lifted. The feet should be placed shoulder-width apart, with one foot slightly ahead of the other. It is preferable for the lifter to place one hand on a fixed object, such as a table or counter. When either of these is unavailable, the lifter may place the opposite hand on their thigh for support. Keeping the back straight and the buttocks outward, the lifter will lower themselves to reach the object's handle. The lifter will then grasp the handle securely and face forward. At this point, the lifter will use the opposite hand and both legs to perform the lift. Before beginning the lift, the lifter should take a deep breath and hold it. Once the lift is completed, the lifter will then breathe out before stepping forward with the load. The partial squat technique is shown in Photograph 30.5.

Overhead Lift[3]

The overhead lift is used to place light to moderate loads onto shelves. Whenever lifting overhead, it is advisable to understand that overhead lifts pose an increased risk of muscle strain. As stated earlier in the chapter, overhead lifts should be avoided whenever possible. One way to avoid overhead lifts is the use of ladders or working platforms. This lift begins with the load already in the lifter's hands. The lifter holds the object firmly and close



FIGURE 30.4
Golfer's lift technique[3] (Source: McNeel, Johnny 2024).



FIGURE 30.5
Partial squat lifting technique[3] (Source: McNeel, Johnny 2024).

to their body, keeping the feet shoulder-width apart and one foot slightly ahead of the other. The lifter should look forward and raise the object to shelf height using the arm and shoulder muscles, breathing out as they lift. As the object is lifted and reaches the shelf, the lifter should shift their weight from the back foot to the forward foot. When the load reaches the shelf, it should be placed on the edge and pushed onto the shelf. An illustration of the overhead lift technique is seen in Figure 30.6.

Straight Leg Lift[3]

The straight leg lift is often used when obstacles prevent bending at the knees. An example of when this lift can be used is the removal of an object from the trunk of a car. Remember that whenever a lift is conducted without bending the knees, the lifter is at greater risk of muscle strain.



FIGURE 30.6
Overhead lift technique[3] (Source: McNeel, Johnny 2024).

To perform this lift, the lifter will stand as close as possible to the object while slightly bending the knees. One key distinction in this technique is to push the buttocks out, while not bending at the waist. If the object that creates the obstacle is stable, such as an automobile, the lifter may place their knees against it and use it as supporting leverage. Grasp the object firmly with both hands and, looking forward, lift upwards with the legs and back straight. While lifting, it is important to breathe out. The straight leg lift is shown in Figure 30.7.

Material Handling Equipment

The first part of this chapter dealt strictly with manual material handling and focused primarily on the lifter. It is now necessary to provide information regarding the equipment that is used in the material handling process. The categories of equipment to be discussed in this section will include storage equipment, engineered systems, and industrial trucks, as well as equipment used in bulk material handling. It is important that employees be aware of the safe operation of equipment used to mechanically move materials. This includes having the ability to determine the most appropriate type

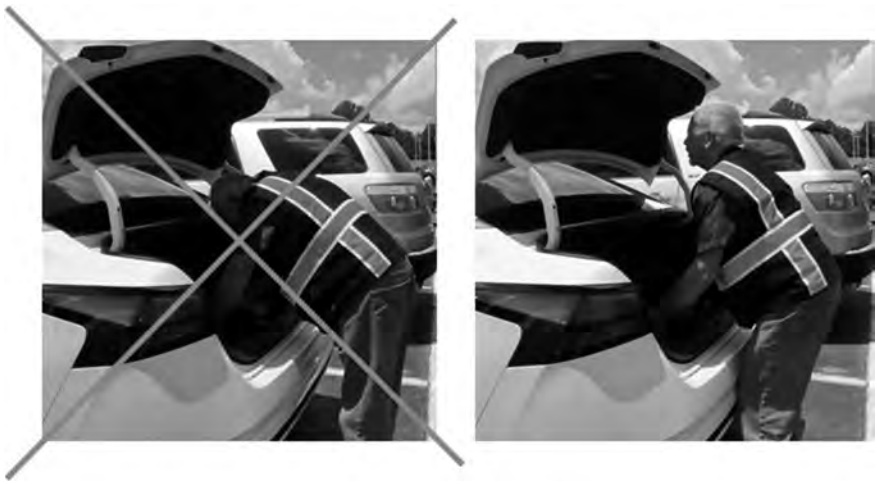


FIGURE 30.7
Straight leg lift technique[3] (Source: McNeel, Johnny 2024).

of equipment to be used based on the weight, size, and shape of the material being moved.[4]

Hand Tools

Pry Bars

The pry bar is commonly referred to as a "crowbar." It is most often used as a leverage device to separate two objects. For example, it is frequently used to assist someone demolishing a building in tearing apart two separate but attached pieces of lumber. So, what does a crowbar have to do with materials handling? There are specialized crowbars, known as "roller crowbars," which are used to lift heavy equipment or materials that sit on the floor enough to get other mechanized lift devices under them. It can also be used to move materials from one location to another. Usually, this tool is used for very short distances.

Whether it is a pry bar or a roller crowbar, there are certain precautions that should take place. When prying, the user must understand that the right amount of pressure or force should be applied. If you apply too little pressure, the material will not be separated or moved. If too much pressure is applied, then the object being separated or moved may dislodge or move excessively, causing injury to the user or others. Always use the proper PPE, including safety glasses and gloves, when using a pry bar. The user should also pry away from themselves and ensure bystanders are not in the line of fire. In addition, crowbars of all types pose the potential threat of creating pinch points. Often, the roller crowbar is designed with T-Bar handles as a preventive measure against pinch point hazards.

Pliers and Tongs

Pliers and tongs discussed in this section are the smaller handheld tongs versus the larger lifting tongs. Tongs are similar to pliers but have specialized gripping ends that are used to keep the hands away from the point of operation. For example, the pliers or tongs may be used to lift manufactured parts, such as hot parts or to hold parts that are hammered or otherwise manipulated. These tools should have handles and grips that are designed to keep ergonomic stresses from the user. As with all hand tools, it is important that the user wear the proper personal protective equipment, such as gloves and safety glasses. Other PPE may be required depending on the type of operation being performed.

Shovels

Shovels are often used to handle bulk materials or to clean up areas used in manufacturing processes. There are various types of shovels, including the following:

- Digging shovels
- Trenching shovels
- Drain spades
- Scoop shovels
- Scrapers
- Edgers
- Post hole diggers
- Trowels and soil scoops

It is not necessary to discuss each type of shovel listed regarding materials handling. Only two of these listed are routinely used in materials handling: digging and scoop shovels. Digging shovels, as the name implies, are used for digging. Therefore, this shovel is designed with that in mind. They typically have sharp edges and are either squared or pointed at the center. Squared points are more commonly used in material handling. The other is a scoop shovel, which is very broad and designed to scoop larger amounts of bulk material.

When selecting a shovel, it is important to understand that blade size and shape depend on the hardness, density, and stability of the materials being shoveled. The less dense the material, the larger the blade size. For example, triangular or round blades with long handles are used for sand and dry earth, whereas square blades with short handles should be used for coarse-grained materials such as gravel, coal, or ore. Smaller blades are selected when you want to limit the weight of the materials.[4]

There are several safety precautions that should be used when shoveling. First, the user should be in good physical shape. The use of a shovel can be physically stressful for the user. Shovels should be ergonomically designed with good grips and handles. One thing to consider is the construction of the shovel itself. Scoop shovels are designed to scoop larger amounts of material, which in turn, will cause the "load" to be heavier. For this reason, many scoop shovels are constructed with composite or plastic materials, with wooden handles. Scoop shovels also tend to have shorter handles. The grip of a scoop shovel is typically perpendicular to the handle. Safety considerations for shoveling include[4]

- Shoveling rates
- Shovel loads
- Throw height; and
- Throw distance

Shoveling rates vary based on many factors, such as scoop weight, physical attributes of the lifter, and shovel task. It is generally accepted that an efficient shoveling rate is estimated to be 18–201 scoops per minute. At this rate, the user will quickly become fatigued. The recommended rate is approximately 15 scoops per minute. At 15 scoops per minute, shoveling should not continue for longer than 15 min at a time before a suitable rest period. Again, the rest period will vary depending on other environmental factors, such as heat or cold.

Shoveling weight should be 10–15 pounds. If this weight is exceeded, then the shoveling rate should be adjusted accordingly. Keep in mind, however, that there should be general guidelines on some maximum lifts. Table 30.1 serves as a guideline on the maximum shoveling weights. Each company should develop its own limits.

TABLE 30.1

Maximum Amount of Material Transported, Continuous Work

Maximum Amount of Material Transported, Continuous Work		
Weight per Minute	**Total Weight per 15 min**	**Conditions**
175—200 lb	1650 lb	Lifts up to 100 cm (40 in) above the ground—compact, non-critical load placement
120-145 lb	1165 lb	Lift routinely above 100 cm (40 in) above the ground
50-75 lb	535 lb	Very precise load placement or shifting load (reduces possible lifting frequency and weight per lift.

Source: https://www.ccohs.ca/oshanswers/ergonomics/shovel.html.[4]

Example 30.1

An employee has been assigned to clean up the over-spill of a bulk material from the sides of a conveyor belt. The scoop shovel will hold approximately 25 lb of a sand-like substance, and the scoop lift is 38 in. (distance from floor to conveyor belt). What is the recommended scoop rate before the employee should take a rest break?

Step 1
Look at the total weight per minute for the activity described. In this particular scenario, the conditions are that the lift is less than 40 in. above the ground. The maximum load for a 15-min time period is 1,650 lb.

Step 2
Calculate the shoveling rate using the following equation.

$$\frac{\text{Maximum Weight}}{\text{15 minutes}} = \text{Weight per minute}$$

$$\frac{1{,}650 \text{ lb}}{15 \text{ min}} = 110 \text{ lb}$$

Step 3
The weight of the material is known to be 25 lb. The weight per minute is known. The scoop rate can now be calculated using the following equation.

$$\frac{\text{weight per minute}}{\text{Total weight per scoop}} = \text{scoops per minute}$$

$$\frac{110 \text{ lbs per minute}}{25 \text{ lbs}} 4.4 \text{ scoops per min}$$

Chain Hoists

Chain hoists are commonly used to lift materials. They are lifting devices where the lifting force is provided by a drum or wheel, with ropes or chains wrapped around the drum or wheel. Chain hoists can operate manually or electronically, depending on the specific model. See Photograph 30.2.

Like shovels, at first glance, chain hoists appear to be simple in nature. These devices, if not properly maintained, can become hazards of their own. The first safety requirement when using any piece of equipment is to ALWAYS follow the manufacturer's recommendations. There are certain inspections/checks that are required for chain hoists. Pre-Operational Inspections include the following:



PHOTOGRAPH 30.2
Chain hoist (Source: McNeel, Johnny 2024).

- Hoists should not be tagged out of service.
- Ensure that all nameplates indicating the model and rating are in place and legible.
- Operate the chain hoist without a load to ensure that it is in good operational condition.
- Check for hoist damage, such as load drift.
- Inspect the hook. Items to look for are cracks, twisting, or any form of deformation such as stretching. Also ensure that the safety latch is present and is fully functional on the hook.
- Inspect the chain for any kind of damage. If wire rope is used instead of chain, ensure that any noted damage falls within manufacturer's acceptable use. Wire damage can include broken strands, kinks, bird-caging, etc. Inspect the chains for elongation.
- Ensure that the wire or rope is properly *reeved* and there is no twisting of the rope or chain. Reeving is the path of the rope between the hoist and the load block.

- Limit switches should be inspected to ensure that the upper limit device stops the motion before the load block strikes any part of the hoist.
- Conduct a general inspection of the hoist and associated parts, such as brake screws, oil leakage, or unusual sounds or feeling.

Each chain hoist will have a maximum load rating on the device. Before lifting a load, the operator must have a good estimate of the load to be lifted.[5]

Non-Powered Materials Handling Equipment

Dolly or Hand Truck

Dollies and hand trucks are some of the most common and useful hand tools used in materials handling. They are also the source of many injuries from strains, sprains, and lacerations. Before using dollies and hand trucks, it is extremely important that the operator be properly trained in their use. This training should include the following:

- Always stretch before attempting a physical task, such as operating a hand truck or dolly.
- Before operating a dolly or hand truck, conduct a pre-operational check to ensure the wheels, frame, and plates are in proper working order.
- Each dolly is rated for a specific load capacity, and this capacity should never be exceeded.
- Two-wheeled hand trucks (most common in materials handling) should have larger boxes or objects placed on the bottom with the smaller objects/boxes on the top.
- Place the load onto the dolly or hand truck, using proper body mechanics.
- Some loads may require straps to secure them from shifting during travel.
- Tilt the load at the top by placing one foot onto the truck while holding the top of the dolly with one hand and the load with the other holding the load.
- Move forward and never backward with a loaded hand truck/dolly. Pushing is less strenuous on the body than pulling.
- If traveling down a ramp, keep the load in front. If traveling up a ramp or slope, keep the load behind you.

- Always walk the travel path prior to transporting a load to ensure that the path is clear.
- Use proper PPE, such as gloves and safety glasses.

If moving 55-gallon drums, there are special dollies that can be purchased. When loading or unloading drums, fingers and hands can become pinched, causing either lacerations or broken bones. Operators should always be instructed to allow enough space and be cognizant of proper hand placement.

Pallet Jacks

Pallet jacks can be either manual or electric. Injuries common to both types of pallet jacks include foot injuries, musculoskeletal injuries (back and shoulder), lacerations, and fractured bones. In addition, property damage can result from improper use of this equipment. As with other materials-handling equipment, a pre-operational inspection of pallet jacks should be conducted prior to their use. A general check of the overall structure of the equipment, including the handles, wheels, and forks must be performed prior to operation. If there is evidence of fluid leaks, the equipment must be locked out and placed "out-of-service" until repairs are made by a competent maintenance technician. The controls should be tested as part of the operational check.

Safe operation of pallet jacks is paramount in preventing injuries and property damage. It is important that personal protective equipment is used during the operation of pallet jacks. Appropriate PPE includes safety glasses, gloves, and safety-toed shoes. Pinch points must always be at the forefront of an operator's mind. Pallet jack travel paths should be observed prior to traveling with a load to ensure that the floor is stable and obstacle or hazard-free. The loads on the pallets should be stable prior to transporting them. Finally, if the pallet jack is powered by electricity, all cords and plugs must be checked before and after use to ensure that there are no exposed electrical conductors.

Powered Industrial Trucks

No discussion or chapter on materials handling can be complete without a review of powered industrial trucks, often referred to as "forklifts." The Occupational Safety and Health Administration has a specific standard on this issue. It can be found in 29 CFR 1910.178. Because of the number of injuries related to powered industrial trucks in recent years, OSHA has been focusing on training and use in order to reduce or eliminate injuries

altogether. When thinking about forklift incidents, many believe that a forklift either struck an employee or a structure, causing bodily injury or property damage, or the employee was involved in a roll-over. Yes, these types of incidents do exist. However, there are many other common types of incidents involving powered forklifts. The following is a list of injuries occurring in 2018 and 2019 that provide examples of the wide variety of injuries and incidents that occur:[6]

- Worker fatally struck by an object falling off a forklift.
- Worker fatally crushed when forklift fell from sky track.
- Worker fatally crushed between forklift mast while performing routine maintenance.
- Worker died in fall from forklift prongs.
- Worker electrocuted when forklift contacted power lines.

The examples of forklift fatalities illustrate the serious consequences resulting from the operation of powered industrial trucks. It is important to also understand the causes of these fatalities, which include lack of or improper training of operators, production factors such as speed or stress, lack of proper tools, attachments, and accessories, poor maintenance, and the age of forklifts. A very controversial topic regarding forklift operation is that of employee behaviors. It is important to clearly understand some of the employee behaviors, such as traveling at excessive speeds, traveling with the loads too high, improper turning, not providing warning signals at intersections and blind spots, allowing riders on the forks or forklift, entering semitrailers without chocking the wheels, horseplay, and failing to adequately conduct pre-operational checks. Employee behaviors can result from management or supervisory complacency, lack of enforcing safety policies, and most importantly, failing to properly train employees.

Training

Injuries from forklifts have escalated OSHA's enforcement policies in recent years regarding powered industrial trucks. Training on the safe operation of powered industrial trucks is at the forefront of many OSHA visits to facilities. A training plan should be reviewed annually to ensure that employees receive the most current and up-to-date information. Again, the standard by which all operators of powered industrial trucks should be trained is 29 CFR 1910.178 for General Industry and 29 CFR 1926.602 for the Construction Industry. These standards require that only trained and authorized operators be allowed to operate forklifts.[7] Training is comprised of formal instruction through classroom lectures or discussion, practical hands-on training, and a practical evaluation of the operator's ability. ***The most recently revised 29 CFR 1910.178 no longer has the requirement that refresher training be***

completed every 3 years. However, there remains a requirement to have each operator evaluated every 3 years. The requirement for initial training is that the operator must be trained before they are permitted to operate a forklift. The only exception is that the "trainee" may operate a forklift for the purposes of training and under the direct and immediate supervision of a competent trainer. Refresher training must be completed (a) when the operator has been observed to operate the vehicle in an unsafe manner; (b) when the operator has been involved in an accident or near-miss incident; (c) when the operator has received an evaluation that reveals that the operator is not operating the truck safely; (d) when the operator is assigned to drive a different truck; or (e) when a condition in the workplace changes in a manner that could affect the safe operation of the truck.[8]

Training must cover the following topics:[8]

Truck-Related Topics

- Operating instructions, warnings, and precautions for the types to be used
- Differences between a powered industrial truck and an automobile
- Steering and maneuvering
- Engine or motor operation
- Visibility
- Vehicle inspections
- Operating limitations

Workplace-Related Topics

- Surface conditions where the vehicle will be operated
- Compositions of loads to be carried and load stability
- Load manipulation, stacking, and unstacking
- Pedestrian traffic in areas where the vehicle will be operated
- Aisleways
- Hazardous locations where the vehicle will be operated
- Ramps and other sloped surfaces
- Any unique hazards or environments where the vehicles may be operated

Types of Forklifts

Powered Industrial Trucks (PITs), commonly known as "forklifts," come in various shapes, sizes, and capacities. For example, forklifts may be sit-down

riders, stand-up riders, motorized pallet jacks, or rough terrain reach forklifts. Forklifts are also classified according to their fuel type, including electric, diesel, and propane. Each type has its own specific safety hazards, but in general, they all have basic training requirements.

Electric Forklifts

One of the great advantages of using battery powered forklifts is that they produce no emissions and virtually eliminate the carbon monoxide hazard associated with most forklift operations. They run much more quietly than forklifts with internal combustion engines. Electric forklifts are powered by large acid-filled batteries. These forklift batteries require recharging or replacing on a periodic basis. Battery charging and changing create many safety hazards that the operator should be aware of. These hazards include[9]:

- Muscle strains due to the heavy weight of the batteries.
- Acid burns/battery explosions.
- Hydrogen fumes resulting from charging.
- Contact with battery cells can cause electrical short circuits, which can burn unprotected skin.

Battery charging and changing areas should be designated for this sole purpose and should be clearly marked and ventilated. A properly equipped battery charging area will have[9]

- No smoking.
- Warning signs posted.
- Adequate fire protection.
- Ample and readily available water supply for flushing and neutralizing spilled electrolyte.
- An eyewash capable of providing a 15-min flow.
- A phone or other means of communication in the event of an emergency.
- Adequate ventilation to avoid the buildup of hydrogen gas during battery charging.
- Soda ash or other neutralization materials in the immediate area
- A dry chemical, CO_2 or foam fire extinguisher.
- Means to protect charging apparatus from damage by trucks.
- Eye protection, such as goggles and/or a face shield.
- Acid-proof gloves.
- Neoprene or rubber apron.

Propane, Gasoline, and Diesel Forklifts

These types of forklifts are grouped together due to the nature of their hazards. Since each of these fuels is used to power internal combustion engines, the primary hazard associated with these forklifts is the buildup of carbon monoxide while operating indoors.[10] The following safety precautions should be strictly adhered to when operating forklifts or any internal combustible engine indoors.[11]

- Do not operate a gasoline/propane/diesel engine for long periods of time in a confined area, such as a truck trailer.
- Shut the engine off when staying inside a small, confined area like a trailer.
- Do not operate a combustion engine within a warehouse, plant, or onboard ship without adequate ventilation.
- Be careful in cold weather. Doors and windows that are normally open may be closed, and exhaust and other gases may concentrate.
- Be careful in small rooms or blocked areas where gases may accumulate.
- Drive sensibly. Avoid racing the engine or idling for long periods of time.
- Properly maintain engines and do not operate an engine requiring service.
- Consider switching to battery-powered forklifts if much of the work is in poorly ventilated spaces or operators may be over-exposed to exhaust byproducts.
- Consider upgrading the ventilation system.
- Install CO monitors to detect levels.[11]

When conducting training, the specific operating instructions that relate to the specific truck being operated should be included. Other topics that should be discussed include differences from automobiles; controls and instrumentation; engine or motor operations; steering and maneuvering; visibility; fork and attachment adaptation, operation, and use; vehicle capacity and stability; vehicle inspection and maintenance that the operator will be required to perform; refueling/charging/recharging of batteries; operating limitations; and other instructions deemed necessary to ensure safe operations.

Preoperational Check

One of the most important aspects of operating a powered industrial truck is performing the pre-operational check. This inspection should be conducted by each operator prior to operating the piece of equipment. This check

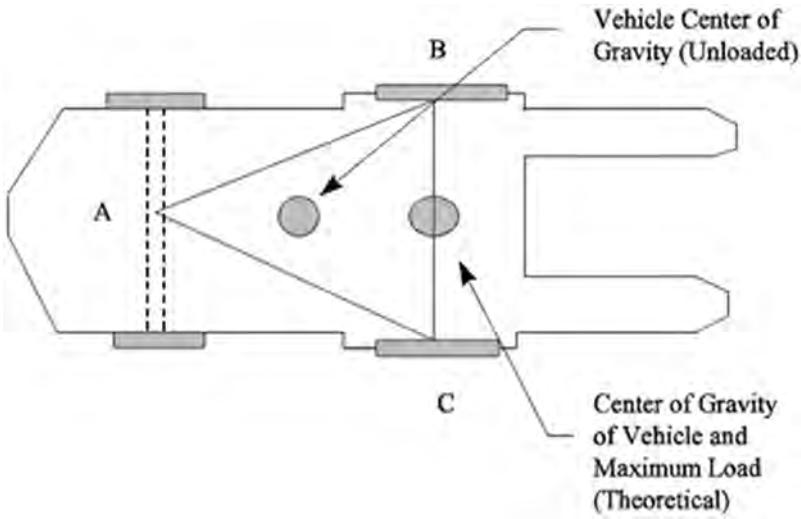


FIGURE 30.8
Stability triangle.[12]

should include an operational check of the steering; brakes; carriage, chains, and forks; hydraulic hoses; hydraulic lift/tilt controls; tires; leaks; fuel level; and oil pressure. In addition to these specific items, propane tanks should be inspected for cylinder damage, along with the valves, nozzles, and hoses. This check should be documented, and a copy maintained on the forklift.

Any training program discussion surrounding truck-related topics should include a detailed discussion on the Stability Triangle (see Figure 30.8).

Most counter-balanced powered industrial trucks have a three-point suspension system. In other words, the vehicle is supported at three points. Even if the vehicle has four wheels, it still has a three-point suspension system. The truck's steer axle is attached to the truck by a pivot pin in the axle's center. When this point is connected to the front wheels with imaginary lines, this three-point support forms a triangle called the stability triangle (triangle ABC shown in Figure 28.1 is where Point A is the pivot point in the rear axle and Points B and C are the front wheels). As long as the center of gravity remains within this stability triangle, the truck is stable and will not tip over.

When the forklift is not loaded, the location of the forklift's center of gravity is the only factor to be considered in determining its stability. In Figure 28.9, the center of gravity is between the axle of the steering wheels at A and the drive wheels at B-C, and it is marked with the arrow as the Vehicle Center of Gravity (Unloaded). In Figure 28.3, the combined center of gravity of the forklift and its maximum load shifts forward toward the load so that it is now located on the line representing the front axle, at the very edge of the stability triangle. While the loaded forklift is still theoretically stable, in practice the combined center of gravity should never reach this line because

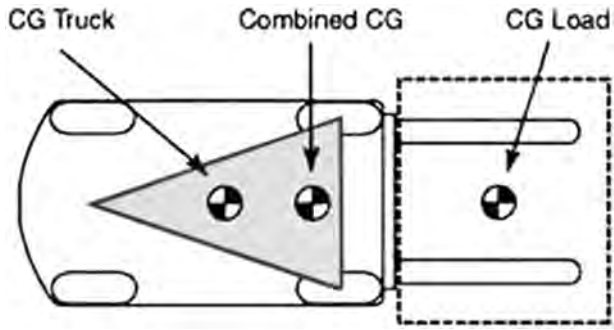


FIGURE 30.9
Center of gravity—loaded.[12]

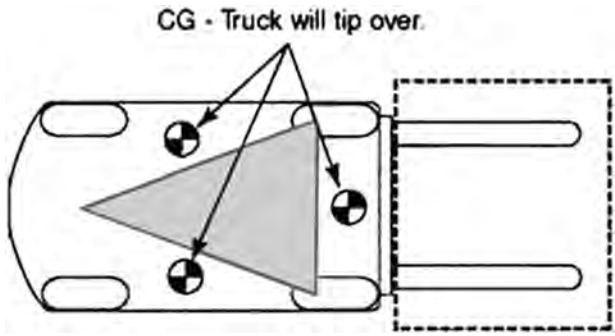


FIGURE 30.10
Shift in center of gravity (truck will tip over).[12]

sudden stops, starts, and turns could shift the center of gravity further out and destabilize the forklift.

As seen in Figures 30.9 and 30.10, a shift of the center of gravity occurs as the forklift is loaded. The forklift is more stable when it is properly loaded than when it is unloaded. However, improper loading, such as loading the forklift beyond its capacity or loading an oversize or wide load without adjusting the weight, will cause the forklift to tip over, either laterally on its side or longitudinally forward. The direction of the tip-over will depend on where the combined center of gravity shifts outside the stability triangle.

In addition to the stability triangle, it is important that each operator be familiar with the following terms and issues:

- Lateral stability is a truck's resistance to overturning sideways.
- Dynamic stability refers to the idea that an unloaded forklift's center of gravity and a loaded forklift's combined center of gravity can shift outside of the stability triangle as a result of certain movements, such as sudden stops and starts, turns, or operating on grades.

- Line of action is an imaginary vertical line through an object's center of gravity.
- Load center is the horizontal distance from the fork's or other attachment's vertical face to the line of action through the load's center of gravity.
- Moment is the product of the object's weight times the distance from a fixed point (usually the fulcrum). In the case of a powered industrial truck, the distance is measured from the point at which the truck will tip over to the object's line of action. The distance is always measured perpendicular to the line of action.

As illustrated in Figure 30.11, the higher the mast is raised, the higher the center of gravity. Therefore, it is critical that the mast be maintained at the lowest level when traveling with a load. What should the operator do in the event of a tip-over? The operator should always be wearing a seatbelt during the operation of the forklift. The seatbelt should assist the operator in staying inside the rollover cage. Should the forklift begin to tip over, the operator should keep their arms and legs inside the caged area and plant their feet on the floor and press down. This helps in keeping the body stable and keeps the legs inside the caged area. It is helpful to lean the body in the opposite direction of the roll.

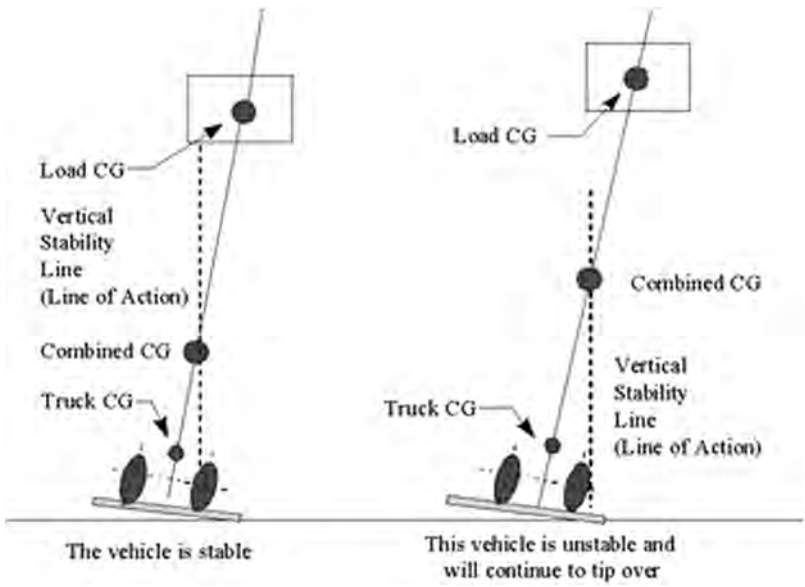


FIGURE 30.11
Vertical stability.[12]

Workplace-Related Topics

Workplace-related training topics should include surface conditions; composition and stability of loads; load manipulation, stacking, unstacking; pedestrian traffic; narrow aisles and restricted areas; operating in hazardous (classified) locations; operating on ramps and sloped surfaces; potentially hazardous environmental conditions; and operating in closed environments or other areas where poor ventilation or maintenance could cause carbon monoxide or diesel exhaust buildup.

Surface Conditions

Operating a forklift involves more than just getting behind the wheel, starting the vehicle, and engaging the transmission. A good overall hazard analysis of the area should be completed prior to operating in each environment. In particular, the operating surface should be considered. The surface a forklift operates on can cause serious safety problems. Loose objects, bumps, or depressions can cause you to lose control of steering, bringing you to a sudden unplanned stop.

stop or cause you to drop your load. A soft dirt surface can cause a wheel to sink and destabilize an elevated load and the forklift. Each of these conditions should be considered in the job hazard analysis, and mitigating steps should be taken to ensure that the risk of operating on such a surface is lowered.

Important safety precautions to take when traveling with a load include[13]:

- Always look in the direction of travel.
- Keep the body inside the cage.
- When moving, the mast must not be raised.
- Sound the horn at intersections and when changing directions.
- Operate the vehicle at safe speeds.
- When turning, watch the rear end swing.
- Watch the clearance under overhead installations.
- Avoid loose objects and holes.
- If the load blocks the view, travel in reverse.
- NEVER carry passengers.
- Pedestrians always have the right-of-way.
- Never eat or drink while operating the vehicles.
- No stunt driving or horseplay.
- NEVER turn on a ramp.

- When traveling up or down a ramp, the load should be upgraded.
- Railroad tracks are crossed diagonally, and
- Never Park within 8 ft of the center of railroad tracks.

Loading Docks and Entering Semi-Trailers

Loading docks can be a hub of activity in manufacturing plants, warehouses, industrial buildings, and distribution centers. These areas are the primary location for the movement of products in and out of the facility. As such, the loading dock area can be one of the more hazardous areas. The loading docks have an increased potential for serious injury, including overturning forklifts, employees being struck by forklifts, slips, trips and fall, trailer–dock separation, unsecured loads, just to name a few. One of the most hazardous conditions exists when semi-tractor drivers mistakenly pull away from the dock when a forklift is inside the trailer. Another hazardous condition, called "trailer creep," results from the repeated entering and exiting of the forklift into the trailer.

To prevent injuries and incidents from these hazards, the common practice is to ensure that the semi-trailers are always chocked. This measure has, unfortunately, proven to be inadequate by itself. An additional measure that is highly recommended is the installation of a "dock-lock" system. An example of a dock-lock system is illustrated in Photograph 30.3.

Along with the receiver, the full system is integrated with an external and internal lighting system. Typically, the system uses red and green lights. When the semi-trailer is fully engaged with the receiver, and the dock plate is in place, the external light will turn red, while the internal light will turn green. This is an indication that the trailer has been secured. When the



PHOTOGRAPH 30.3
Example of a dock-lock system receiver (Source: McNeel, Johnny 2024).



PHOTOGRAPH 30.4
External dock-lock system lights (Source: McNeel, Johnny 2024).

forklift operator has completed the loading of the trailer, they will manually switch the internal light from green to red, which also changes the external light from red to green. The internal and external lights are shown below in Photographs 30.4 and 30.5.

Dock plates should be inspected prior to use and on a periodic basis. Dock plates should be constructed of materials designed for a specific rating to carry the intended loads. Dock plates should also be secured in position to prevent slipping.[14] Oftentimes dock doors are left open, especially in the summer months. The edges of the dock should be protected to prevent forklifts or persons from falling. This can be accomplished by the installation of bollards, guardrails, or netting which is rated to withstand the weight of a forklift.

Note: Before a Forklift enters a semi-trailer, the operator must conduct a comprehensive inspection of the walls and flooring to ensure that there are no holes or rotten decking.

Traveling Up and Down Ramps/Slopes

Traveling up and down ramps and slopes with a load presents a significant potential for the forklift tipping over or the load falling off the forks. Special precautionary measures need to be taken when performing this activity.



PHOTOGRAPH 30.5
Internal dock-lock system lights (Source: McNeel, Johnny 2024).

Loads should always be secure before traveling with a load. When traveling up a ramp or slope with a loaded truck, it should be driven forward with the load on the upgrade side. When traveling down a ramp with a load, the forklift should be driven in reverse. Again, the load should always be on the upgrade side. When there is no load on the forklift, it should be driven with the forks on the downgrade side of the ramp or slope.[13] **One key safety precaution regarding ramp or slope travel is to never turn the forklift on a grade.**[16]

Conveyors

Conveyors can be useful equipment in moving products or materials from one location to another. They help reduce the need for forklifts and other powered vehicles. They do, however, present their own safety-related issues. Conveyors can be gravity or powered. Gravity conveyors have rollers, wheels, or chutes and move products by gravity, as the name implies, or by manually pushing the product along. Specific hazards associated with gravity conveyors include pinch points between products or products falling off conveyors. Adequate protection and warning signs should be in place prior to operation.[15] Powered conveyors use belts, rollers, slats, or buckets that are powered by gears or drive belts. Some of the same hazards in gravity conveyors exist in powered conveyors, but with additional hazards, such as electrical power. When working on these systems, it is critical that the power source be

deenergized and the equipment locked out prior to performing any maintenance. With powered conveyors, there is also the potential for static electricity buildup. Guarding of rollers, as well as tail and head pulleys, must be in accordance with OSHA's machine guarding standards, located in 29 CFR 1910.212. Finally, ergonomic issues and concerns must be addressed while working around conveyors. It is important that conveyors be located at the correct vertical height to prevent ergonomic stresses whenever possible. If a bulk material is being transported by conveyors, it is almost guaranteed that there will be spillage at some point that must be cleaned up.[17]

Storage Racks

While there is very limited information in 29 CFR 1910.176 (Subpart N) regarding storage racks specifically, the General Duty Clause can be used to cite employers for failing to take necessary actions to protect employees from the hazards associated with storage racks. Some of the most common storage rack incidents involve the following:

- Employees raised the product too high on the shelves, causing the separation of the cross members from the vertical members.
- Storage racks not being anchored to the floor.
- Exceeding storage capacities of the racks and shelving. Each horizontal and vertical member of a storage rack should be engraved with the load capacity of that structural member. Neither of these ratings should be exceeded.

The standard in 1910.176 does state that the storage of material shall not create a hazard. In addition, 29 CFR 1910.159 states that the minimum vertical clearance for fire sprinklers is **18 in.**.

Key Information to Remember on Materials Handling

1. When manual lifting must be performed, key principles include reducing the weight and size of packages, getting assistance when needed, lifting should be done with the legs, keeping the back straight, avoiding twisting, and avoiding overhead lifting.
2. The Power Lifting Technique allows lifts to be completed without bending the knees below 120° angles, which places less stress on the lifter's back.
3. When using hand tools for materials handling, it is important that the proper personal protective equipment be worn, including gloves,

safety-toed shoes, and safety glasses and other PPE may be required depending on the operational environment.

4. Shoveling rates are based on the maximum 15-min weight limit and the individual shovel/load weight.
5. Users of materials handling equipment should ALWAYS consult and follow the manufacturer's recommendations.
6. Pinch points are very common hazards associated with dollies and hand trucks.
7. Initial forklift training is required BEFORE an employee is permitted to operate a forklift. During forklift training, forklift operation must be conducted under the direct supervision of a competent trainer.[16]
8. Refresher training must be completed (a) when the operator has been observed to operate the vehicle in an unsafe manner; (b) when the operator has been involved in an accident or near-miss incident; (c) when the operator has received an evaluation that reveals that the operator is not operating the truck safely; (d) when the operator is assigned to drive a different truck; or (e) when a condition in the workplace changes in a manner that could affect the safe operation of the truck.
9. Preoperational inspections should be conducted by each operator prior to operating the piece of equipment.
10. The center of gravity on a forklift will change based on the weight and height of the load on the forks.
11. A comprehensive inspection of the semi-trailer must be conducted before a forklift enters to either load or unload materials.

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31

Safety Management System

What is a "safety management system" and how does it differ from the traditional approach to safety management using safety programs. This chapter will attempt to answer this question and provide a good understanding of the details and benefits of a safety management system. A useable definition of what a "safety management system (SMS)" is will be provided. The goals of an SMS will be provided and discussed. In addition, four (4) of the more popular systems will be provided as examples, including OSHAS 18001, ILO-OSH 2001, ANSI Z-10 and CSA Z1000 are discussed in detail within the chapter. Deming's 14-point Principles of a Quality Management System, along with the PDCA model will be reviewed and discussed in significant detail.

Safety Management System (SMS) Definition

A *Safety Management System* (*SMS*) can be defined as a comprehensive management system that provides a platform for the integration of safety program elements, including responsibilities, policies, individual procedures, and the overall goals and objectives, with the end result being continuous improvement in the control of risks. The major goals of a safety management system are to:

- Provide a systematic approach for an organization to manage risks
- Identify risks and implement effective controls
- Serve as a continuous improvement process
- Provide an early means to determine when a process is non-compliant
- Provide areas of specific responsibilities

Components of a Safety Management System (SMS)

There are four major components of a Safety Management System, including:[1]

- Safety Policy
- Safety Risk Management

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FIGURE 31.1
Components of a safety management system.

- Safety Assurance
- Safety Promotion

These components are also identified in Figure 31.1.

Safety Policy

An integral part of any SMS, as seen in Figure 31.1, is the development and inclusion of a Safety Policy. The safety policy demonstrates management's commitment to the safety program and to the safety management system.

Policy Statement

As part of the safety policy, management develops a written document, known as a "policy statement," that communicates this commitment and must include a statement on how the policy will be introduced and sustained within the structural organization. The policy statement should include:

- Management commitment statement
- Purpose and benefits of the SMS

- Method of monitoring safety performance
- Commitment by management to allocate financial and human resources to accomplish the goals
- Clear employee expectations to participate in the system

Organizational Structure

The safety policy should include an overview of the organizational structure that will be responsible for the safety management system. This organizational structure may not include the corporate structure but must include those specific positions that will be responsible for ensuring the success of the safety management system. The Safety Manager of the organization should be at the head of the SMS organizational structure, as they are in a position to monitor compliance and non-compliance more frequently, as well as take corrective actions sooner.

Procedures

The SMS will consist of multiple and widely varied procedures, such as training, lockout-tagout, confined space, etc. In addition to specific safety procedures, the procedure to comply with the requirements of the safety management system must also be included. Some of the procedures regarding the SMS itself might include:

- Recordkeeping
- Record retention
- Periodic and annual reviews
- Management of change
- Auditing procedures
- Management of non-compliant areas

Safety Risk Management

The Safety Risk Management (SRM) component provides a detailed guide to determining the need for, and adequacy of, new or revised risk controls based on the assessment of acceptable risk. An example of such an assessment, both quantitative and qualitative methods, can be viewed in Chapter 24 of this text. A formal process within the Safety Management System (SRM component) may be composed of the following:

- Description of the system
- A method and process for identifying the hazards (hazard identification)
- Assessing the hazard or risk

- Analyzing the risk
- Controlling the risk by implementing corrective measures
- Monitoring the risks and hazards to ensure that the corrective measures have been effective in controlling the risk

Safety Assurance

The Safety Assurance component is an extremely important one, in that it provides for early detection of non-compliance issues, areas in need of improvement and successes. This is done through the following means, just to name a few:

- Daily, weekly, and monthly reports (i.e., safety inspections, training, etc.)
- Audits, inspections, and evaluations

The audits of the actual SMS compliance are in addition to safety-related audits.

- Employee reporting
- Data analysis
- System assessments

Safety Promotion

In order to gain widespread acceptance and compliance, it is incumbent upon management to demonstrate the potential benefits. This can be done by establishing a solid safety culture through a well-prepared policy statement described above. The safety culture will be developed over time by providing the required training within the SMS framework. Management must also advocate and demonstrate a positive safety culture. In other words, management should put actions to their intentions by providing both financial and human resources to accomplish the goals and objectives of the SMS. In addition, good communication must exist from both a top-down and bottom-up method. Finally, safety promotion includes establishing clear and concise goals and objectives. The status of these goals and objectives should be discussed openly and frequently enough to keep employees informed. By including employees in the process, management shares some of the ownership in the programs and procedures with the employees.

Deming's 14 Points for Total Quality Management

Before discussing individual Safety Management Systems, it is necessary to provide some of the basic guidelines of total quality management. One of the pioneers in the field, W. Edwards Deming, who helped the Japanese manufacturing industry improve its manufacturing and business effectiveness, had 14 key points in total quality management. These points are also known as Deming's Principles of Total Quality Management. These points are listed below:

1. Create constancy of purpose for improving products and services
2. Adopt the new philosophy
3. Cease dependence on inspection to achieve quality
4. End the practice of awarding business based on price alone; instead, minimize total cost by working with a single supplier
5. Improve constantly and forever every process for planning, production, and service
6. Institute training on the job
7. Adopt and institute leadership
8. Drive out fear
9. Break down barriers between staff areas
10. Eliminate slogans, exhortations, and targets for the workforce
11. Eliminate numerical quotas for the workforce and numerical goals for management
12. Remove barriers that rob people of pride in workmanship and eliminate the annual rating or merit system
13. Institute a vigorous program of education and self-improvement for everyone
14. Put everybody in the company to work accomplishing the transformation

PDCA Model

Every quality management system has at its core some version of the PDCA model, which was also popularized by W. Edwards Deming. The model is quite simple in concept. It is simply Plan-Do-Check-Act (see Figure 31.2).

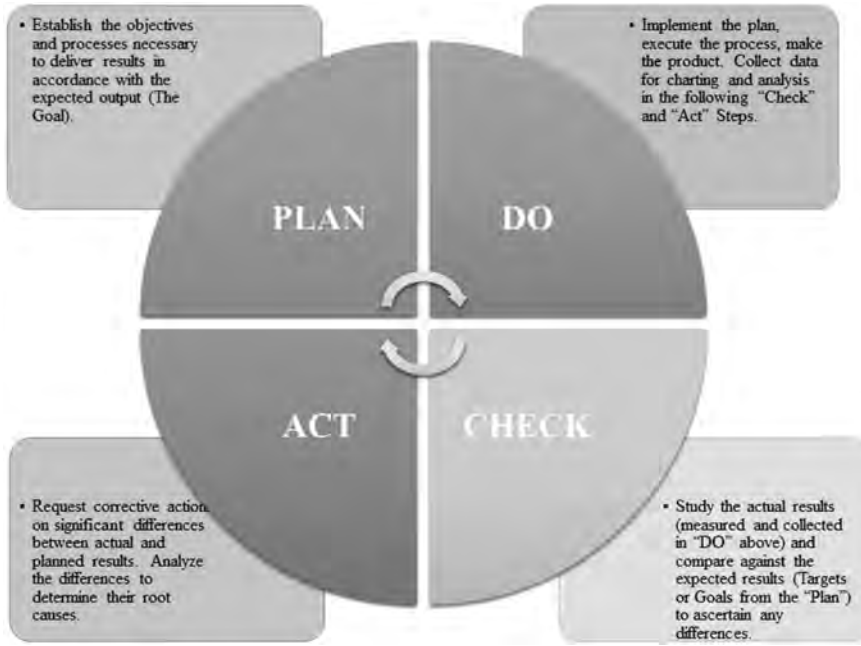


FIGURE 31.2
PDCA model.

As shown in the PDCA model above, the cycle begins with planning and is completed during the first cycle with Act. What you will also notice is that the model shows a continuous cycle. This means that when the first goal is successfully met, the bar should be raised. This will be discussed in the demonstration of the PDCA model being used for problem-solving.

Plan

In this step, the problem is clearly identified and assessed, and a plan is developed to correct or solve the problem. Individual steps taken in order under the Plan phase include:

- Define the problem. The problem should be focused on the root cause of the issue
- Establish containment
- Form the team
- Collect data
- Brainstorm potential causes
- Discard causes that appear irrelevant
- Identify root causes

- Propose solutions
- Choose solutions
- Predict the results
- Plan implementation

Do

The plan is executed in order to solve the problem.

Check

In this phase, the results of the plan execution are measured and used to validate or invalidate the solutions.

Act

The following steps are included (in order) under the Act phase of problem solving:

- Standardize the solutions
- Remove containment
- Share lessons
- Select a new problem or raise the bar on the existing one and repeat the cycle

Figure 31.3 illustrates the individual details of a problem-solving technique using the PDCA model.

Review of Common Safety Management Systems

To help understand safety management systems, several of the more common safety management systems will be discussed. These include OHSAS 18001, ILO, ANSI- Z10, and CSA Z1000.

OHSAS 18001

OHSAS 18001 is highly recognized as one of the leading safety management systems used in the United States. However, it was not developed in the United States, but instead in coordination and cooperation with Spain, Malaysia, the United Kingdom, and other European standards organizations.

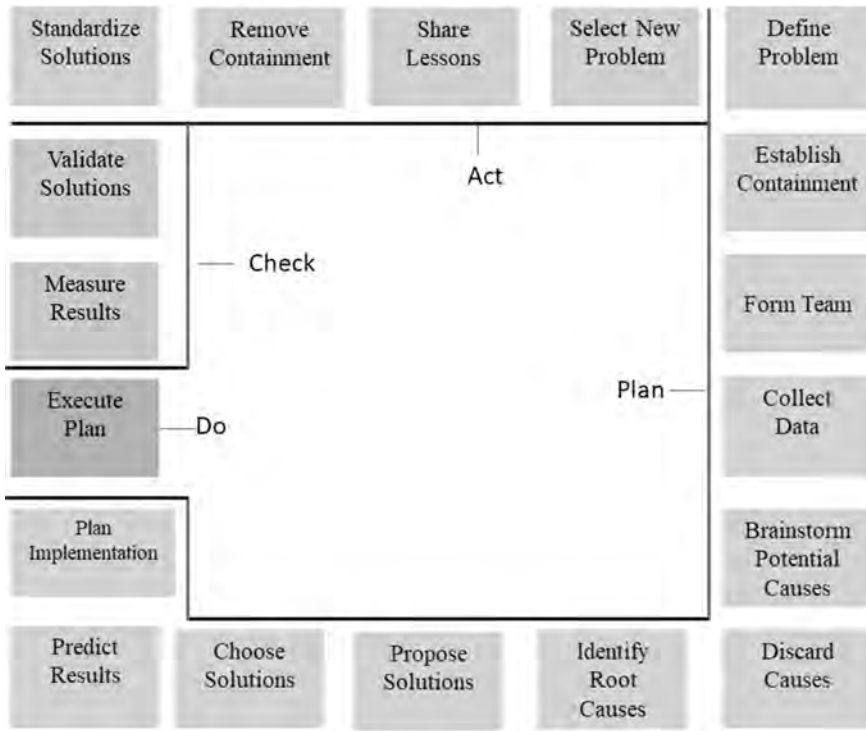


FIGURE 31.3
Problem-solving technique using the PDCA model.

It has become a British Standard for OHS management systems since being updated in 2007. The elements of OHSAS include the following:

- General requirements
- Occupational Health and Safety (OH&S) policy and commitment
- Planning
  1. Hazard identification, risk assessment, and control
  2. Legal and other requirements
  3. Objectives
  4. OH&S management programs
- Implementation and operation
  1. Structure and responsibility
  2. Training, awareness, and competence
  3. Consultation and communication
  4. Documentation

5. Document and data control
6. Operational control
7. Emergency preparedness and response

- Checking and corrective action
  1. Performance measurement and monitoring
  2. Accidents, incidents, non-conformances, and corrective and preventive actions
  3. Records and records management
  4. Audit
- Management review

While OHSAS requires the above elements and sections in the system plan, it does not mandate how each of these is to be done. The details of the plan are to be developed by the individual companies. For example, under document retention, OHSAS does not require that documents be retained in any specific manner, but it does require that whatever plan is implemented by the company be monitored and corrective actions taken when non-compliance issues are found. This system requires that clear levels of authority and lines of communication be established. Under this system, the company must ensure its success through frequent internal and external audits. This plan provides a blueprint for a company to develop a safety management system to ensure the health and safety of employees, contractors, and visitors.

Any system will have advantages and disadvantages over others. These advantages and disadvantages are discussed in the following sections.

Advantages

The primary advantages of the OHSAS 18001 system are as follows:

- Widely accepted and recognized system throughout the globe
- Increases employee as well as management engagement in the safety system
- Increases the potential for improved company and product acceptance, thereby increasing the opportunity for business expansion
- Provides a basis for improving overall safety risk management, thus reducing insurance premium costs
- Helps in the reduction or prevention of production delays and downtime from injuries
- Provides a systematic platform for communication
- Serves as the platform and pathway for continuous improvement

Disadvantages

The major disadvantages of the OHSAS 18001 system include the following:

- Cost of safety management system external auditing
- Human resource commitment from both management and employees
- Other costs include standards purchase, increased auditing, and potential system bureaucracy

Depending on how one looks at it, OHSAS 18001 focuses primarily on hazard reduction, which can be an advantage or a disadvantage. Other systems to be discussed will focus on risk reduction versus hazard reduction.

ISO 14001

ISO 14001 is an internationally accepted standard that sets out the requirements for an environmental management system. The purpose of ISO 14001 is to achieve a balance between the environment, society, and the economy, which is considered essential in meeting the needs of the present while preserving the future. Like all ISO systems, ISO 14001 includes:

- Scope
- Normative references
- Terms and definitions
- Context of the organization
- Leadership
- Planning
- Support
- Operation
- Performance evaluation
- Improvement

ISO 45001

ISO 45001 is a system developed by ISO (International Organization for Standardization). ISO, itself, is a globally recognized leader in the standardization industry. ISO 45001 has a higher-level structure than OHSAS 18001 and includes the following outline:

- Scope
- Normative references
- Terms and definitions

- Context of the organization
- Leadership
- Planning
- Support
- Operation
- Performance evaluation
- Improvement

ISO 45001 was based initially on OHSAS 18001. However, ISO 45001 focuses more on risk management versus hazard management. As part of this, there was an increased focus on determining both the internal and external environments of a company and their customers. In other words, the needs of the various government agencies in the form of regulations and the needs of various stakeholders. Clear and meaningful objectives are to be developed, and plans made to achieve objectives are also a primary focus of the system. Monitoring and system performance reviews must be conducted on a frequent basis.

ILO-OSH 2001

The International Labour Organization (ILO) is an international agency with the purpose of bringing together governments, employers, and workers of its member States to set labor standards, develop policies, and devise programs promoting decent work for all women and men.[2]

ILO-OSH 2001 is an overall system designed to work with other systems that an organization might choose to utilize. The core sections of the system are as follows:

- Policy
- Organizing
- Planning and implementation
- Evaluation
- Action

It is built around the PDCA model. The key components of the ILO-OSH 2001 system can be viewed graphically in Figure 31.4.

ANSI Z10

The American National Standards Institute (ANSI), in coordination with the American Industrial Hygiene Association (AIHA), began work on ANSI Z10 in 1999. This standard was a voluntary consensus standard, meaning that



FIGURE 31.4
Key components of ILO-OSH 2001.



FIGURE 31.5
ANSI Z10 process

the standards are generally recognized and sound principles throughout the globe and the safety profession to enhance the overall health and well-being of employees. As with other safety management systems, ANSI Z10 is a framework where the details must be tailored to fit the individual needs of companies. The basic components of ANSI Z10 include (see Figure 31.5):

1. Management leadership and employee participation
2. Planning

3. Implementation and operation
4. Evaluation and corrective action
5. Management review

The basic process is presented graphically in Figure 31.5.

A useful outline of an ANSI Z10 written program may include the following:[3]

- Management leadership
- OHSMS policy
- Responsibility and authority
- Employee participation
- Review process
- Assessment and prioritization
- Objectives and implementation plans
- Risk assessment
- Hierarchy of controls
- Design review and management of change
- Procurement
- Contractors
- Emergency preparedness
- Education, training, and awareness
- Communications
- Document and record control
- Monitoring and measurement
- Incident investigation
- Audits
- Corrective and preventive action
- Feedback to the planning process
- Management review (process, outcome, and follow-up)

Summary

Regardless of the specific safety management system (SMS) that a company selects to build its framework, they all have in common the end goal of decreasing employee injuries and improving the safety management of an organization in a systematic fashion. Specific benefits of all SMSs are:

- Improved management of risks and hazards
- Provide a framework to change an organization's safety culture
- Maintain compliance with governmental standards and regulations
- Improve the overall performance of the organization

Key Points to Remember on Safety Management Systems

1. A *Safety Management System* (*SMS*) can be defined as a comprehensive management system that provides a platform for the integration of safety program elements, including responsibilities, policies, individual procedures, and the overall goals and objectives, with the end result being continuous improvement in the control of risks.
2. The safety policy demonstrates management's commitment to the safety program and to the safety management system.
3. The Safety Manager of the organization should be at the head of the SMS organizational structure, as they are in a position to monitor compliance and non-compliance more frequently, as well as take corrective actions sooner.
4. The Safety Risk Management (SRM) component provides a detailed guide to determining the need for, and adequacy of, new or revised risk controls based on the assessment of acceptable risk.
5. Every quality management system has at its core some version of the PDCA model, which was also popularized by W. Edwards Deming. The model is quite simple in concept. It is simply Plan-Do-Check-Act.
6. The purpose of ISO 14001 is to achieve a balance between the environment, society, and the economy, which is considered essential in meeting the needs of the present while preserving the future.
7. ISO 45001 was based initially on OHSAS 18001. However, ISO 45001 focuses more on risk management versus hazard management.

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32

Site Security

Today's safety professional has many duties that have been added to their positions over the years, including safety, industrial hygiene, environmental and site security. Chapter 32 will provide basic information on the physical security of the site. Detailed information and Information Technology (IT) security is not provided within the chapter. For a deeper look into the topic an IT or security professional should be consulted. With that being said, the need for physical security and protection of employees becomes more evident every day. A few of these reasons are listed below:

- Employee protection
- Equipment protection
- Homeland security concerns (depending on the manufacturing or storage facility)
- Loss prevention
- Insurance requirement

This chapter will help safety professionals with limited budgets to conduct basic site security assessments, which is one of the first step in preventing injuries, equipment losses and inventory losses.

Site Security Plan

It is important to have a plan for your site to prevent any type of breach or infiltration of protected sites. Included in a site plan are the following components:[1]

- Site Information
- Management policies
- Physical security measures

Each of these will be discussed to provide insight into the site protections.

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Site Information

The following components are needed to address the various types of emergencies and issues that may result from a breach:

- **The name of the site**: Make sure that it is the legal name of the company which is used on business licenses and permits. Note: Oftentimes, a site may change ownership after 30 years, and people know it by a different name. If this is the case, you may want to include an aka (also known as) name.
- **The site address**: This must be the physical location of the site and not the mailing address, such as a post office. It must be the physical address for emergency responders to locate the property.
- **General manager**: Provide the name, telephone number, including mobile numbers at which the general manager may always be reached.
- **Products and services**: Provide a general description of the products and services provided, including any specific hazardous materials that are likely to create environmental or security concerns. Certain loss of chemicals is required to be reported to the Department of Homeland Security.
- **Number of employees**: Provide, as accurately as possible, the number of employees working on the site. This will aid in recovery operations, if necessary.
- **Operating hours**: The plan should have a description of the normal operating hours.
- **Site area**: Provide as detailed a description of the property as possible. The plan should include a detailed map that shows entrances and exits, emergency shelters, fire protection equipment, the location of hazardous materials, etc.
- **Neighborhood**: A general description of the neighborhood should be provided in the plan. For example, if the facility next to you is a petroleum refinery, it would be worth noting in the neighborhood description.
- **High risks**: This section should list "ALL" areas of special concern, such as the server room, hazardous materials storage areas, storage tanks, shipping and receiving areas, etc.

Risk priorities can be determined using a standard risk matrix, such as in Table 32.1.

TABLE 32.1
Risk Matrix

	SEVERITY			
LIKELIHOOD	**Catastrophic**	**Critical**	**Marginal**	**Negligible**
Frequent	High	High	Medium	Moderate
Probable	High	High	Medium	Moderate
Occasional	High	Medium	Moderate	Low
Remote	Medium	Moderate	Moderate	Low
Unlikely	Moderate	Moderate	Moderate	Low

Management Policies

Management policies are made up of individual policies that address key risk factors, including employee access and security, emergency response procedures, crisis management policies, workplace violence, and reporting policies. While management policies are a composition of numerous policies and procedures, the site must include a general description of them in a comprehensive site security plan.

Physical Security

The physical security of a facility is concerned with the protection of personnel, hardware, software, networks, and data caused by physical actions. The major concerns regarding physical security include fire, flood, natural disasters, burglary, theft, vandalism, and terrorism. To prevent such incidents, this chapter will discuss the following individual physical security concerns:

- Access control
- Employee security
- Information security
- Material security
- Equipment and facility protection
- Emergency response
- Workplace violence prevention

Access Control

Physical security begins with controlling access points to the facility. If a facility has no access controls, it is extremely susceptible to unauthorized infiltration, which can and probably will result in a future incident. Simply placing signs that state, "All Visitors Must Report to the Front Office" is

not adequate. Physical barriers such as doors, fencing, walls, gates, guards, badge systems, locks, alarms, cameras, or other control mechanisms must be in place to prevent unauthorized entry to the site. When it comes to access control, the following considerations must be addressed:

- Entry to the facility is controlled and/or restricted to authorized personnel only
- Entry procedures, such as badges, access cards, biometrics, etc.
- Visitors and contractors must be accompanied by or approved to be on site by a project manager or an employee of authority (manager or supervisor)
- Sign-In Logs maintained
- Identification of visitors and contractors to other employees
- Safety briefing of visitors and contractors
- Procedures addressing searches, if necessary
- Shipping and receiving procedures, including truck drivers
- Sensitive areas require special access and are designated as such
- Breaches of security—locks changed, review of the plan, etc.

Employee Control

Employees are a company's most valuable asset. They can, however, become a serious threat to the security of the company. Therefore, before a candidate becomes an employee, it is vital that a full background investigation or screening be completed on the potential employee. This is especially true for candidates being hired for sensitive positions, such as security, IT, or any position that has access to employee records or software systems. Once the candidate has been hired and begun work with the company, it is incumbent on the employer to ensure that the employee is trained in the safety and security procedures of the company. Furthermore, ID cards or access cards should be issued to the employee, who will also be instructed to maintain control of the cards or badges. If lost, the employee should be instructed to report the loss immediately upon realizing the loss to the appropriate manager or supervisor. All employees should be trained to report unknown or unauthorized personnel without the proper identification.

Information Security

The first step to controlling information within the company is to have a document or information control policy in place. This policy should include how both electronic and paper records are maintained and stored, the protection of these records, how long they will be retained, and the procedures for destroying outdated documents.

Secondly, controlling access to this information by physical means is extremely important. Server rooms should be physically protected from unauthorized personnel. Access to the server room should be limited to key personnel, such as IT or maintenance employees. Vendors, including fire protection services, should always be accompanied by a manager-level employee.

Employees should be periodically trained in IT and cyber security. In addition, employees should be routinely and periodically tested by means such means as emails originated by IT personnel requesting prohibited information or engaging in phishing activities.

Other threats that must be addressed regarding information security include the following:

- Fire
- Vandalism
- Unauthorized entrance
- Periodic backup of files
- Storage of backup materials off-site
- Control of information through emails or faxes

Material Security

Material or inventory loss poses a significant threat to a company's financial security. This loss can result from employee theft, fire, or other incidents. This section will focus on employee theft. It is first necessary for a company to identify potential materials that are susceptible to employee or terrorist theft. Such items may include computers, inventory, precious metals, toxic chemicals, explosives (depending on the industry, of course), biohazards, or radioactive materials. A proactive plan to limit access to these materials must be developed to provide strict controls and prevent theft. For the more hazardous materials, including chemical, explosive, biological, and radiological materials, there must be continuous monitoring of the quantity, use, and transfer or transport. Physical access, badging, alarms, X-ray machines, and explosive sniffing dogs are a few control measures that can be used to prevent threats. Periodic inventory is another control measure to provide early detection of losses. Employee searches are very controversial. Before implementing an employee search program, it is highly encouraged that you consult the legal department for help in drafting such a policy.

Equipment and Facility Protection

As has already been discussed, public access to the facility should be limited to as few entrances as possible. Access control measures have been included in the sections above. What has not been discussed is vehicle access to the facility. A major part of any manufacturing facility is the shipping and

receiving department. As such, vehicles cannot be eliminated from entering the facility property. A vehicle should enter through a single-entry point that is controlled by security officers, who will review the shipping orders, driver identification, and the materials being brought onto or carried off the property. While shipping, the shipping employee should be the individual who loads the vehicles, based on the shipping papers. Vehicles should be prohibited from entering the site except through an authorized entry point.

Typically, from a physical security viewpoint, equipment and facility protection are improved by physical barriers. Fencing is one such barrier. Fences should be located at distances far enough from buildings or materials to prevent using the fence itself to gain access to the property. For example, if you have storage containers that are within two feet of the fence, a person attempting to gain access to the facility may simply climb the fence or use an extension ladder to scale one side, while exiting the fence using the storage containers.

Depending on the size of the facility, the employer may elect to employ the services of roving patrols. If this is the case, it is wise to install devices for the patrols to check in. The devices are installed at critical locations, and the patrol will log the point using an electronic device, such as a scanner. This check-in procedure also provides an electronic record for the security officer. Roving patrol routes should be altered frequently so as not to form a pattern that likely infiltrators can determine. One controversial aspect of having security officers is whether to arm them. This is not an easy decision, but one that should be made in full consultation with legal counsel and consideration of the potential threats.

Electronic monitoring devices have been improved to protect the integrity of the facility. Drones are becoming very popular in the security of facilities. In addition, they may eliminate the need for employees to place themselves in harm's way. An example of this is when you have a gauge that must be read on top of a silo or tank, drones may be used to read the gauge instead of having an employee risk the climb. Another electronic device that proves useful is interior and exterior cameras.

Emergency Responses

No site security plan would be complete without including specific emergency response procedures. The requirement to have an emergency response plan lies in the authority of 29 CFR 1910.38 and 29 CFR 1926.35. The time to develop a plan is not during the middle of an emergency. This plan should be developed prior to emergencies, and employees trained on the plan periodically and frequently enough to maintain proficiency. Training on the Emergency Response Plan is required, at a minimum, annually. Emergency response procedures are based on the potential threats to an organization. Most plans will include the following topics:

- Fire
- Medical

- Bomb threats
- Inclement weather
- Power outages
- Chemical spills
- Active shooter
- Media events

Fire Emergencies

Fire represents one of the more serious emergencies to face any facility. An employer has the responsibility of developing procedures to prevent fires from occurring and a means by which employees can escape in the event one does occur. An adequate number of fire extinguishers and detection devices must be present. Evacuation maps indicating exits, locations of fire extinguishers, medical kits, and AED's should be posted throughout the facility. Fire drills should be conducted frequently and at least annually. In addition to the fire evacuation maps, the procedure should also provide key personnel (by position) who will act as supervisors in the event of an evacuation, as well as a list of assembly points where employees will gather. The fire supervisor or warden will be responsible for taking employee accountability. Taking accountability is easier said than done. A means of knowing who is present or absent on the day of the fire must be developed. Should the fire department be called, there must be a person designated by position to stand outside the facility to direct the fire department to the specific location.

Medical Emergencies

The contact number (if not 911 system), along with the physical address of the facility should be clearly indicated in the plan. The person contacting 911 should be trained to provide key information such as the number and type of injuries, current status, known medical allergies, etc. As with fire emergencies, an employee must be designated by position to stand outside the facility to direct emergency responders to the specific location of the injured employees. The plan should also provide a list of key individuals who should be contacted and at what times (e.g., the general manager should be contacted immediately after the emergency conditions have subsided or as early as possible).

Bomb Threats

Bomb threats are usually called in through the main telephone line of the company. However, this is not always the case. All employees should be trained to react to a bomb threat. The following minimum steps are recommended when dealing with a bomb threat:[2]

- Remain calm throughout the call

- Notify authorities immediately
  1. Notify the facility manager via other means (i.e., email, cell phone, etc.)
  2. Call 911 or your local law enforcement if no facility supervisor is available
- Pay attention to accents, keywords, or any other unique identifying traits or comments of the caller
- Keep the caller on the line if possible. Be polite and show interest to keep them talking
- DO NOT HANG UP, even if the caller does
- If possible, signal or pass a note to other staff to listen and help notify authorities
- Write down as much information as possible
  1. Caller ID Number
  2. Exact wording of threat
  3. Type of voice or behavior
- Record the call, if possible
- Be available for interviews with supervisors and law enforcement
- Follow the instructions exactly as given by law enforcement

Inclement Weather and Natural Disasters

An emergency response plan dealing with inclement weather depends on several factors: weather condition (type), facility assets, and the time available to respond. For example, the response to a tornado will be different from that of a hurricane. The one common criterion for all types of inclement weather is that there should be a plan and training of employees prior to an actual emergency.

Tornadoes are events that allow for very limited response times. There are areas where tornadoes are common that have early alert systems, but they are also limited to warnings and watches. A facility should have pre-designated shelters for employees to enter and remain until the emergency has passed. When selecting a shelter-in-place site, the following should be considered:[3]

- Small interior rooms
- Hallways on the lowest floor
- Areas away from windows
- Remain sheltered until the tornado has passed.

Undoubtedly, there will be the occasional employee who will refuse to shelter and leave the premises to go home to be with family. There is nothing that can be done in a case such as this. If this occurs, a supervisor must be notified, and the employee's information recorded.

Hurricanes provide the luxury of time to prepare. Typically, there will be at least 5 days' advance notice. This allows the employer time to secure loose

equipment, such as trash cans and smaller objects that can become projectiles. In addition, it allows the employer to plan to close the facility if need and to notify employees. Most importantly, follow the instructions of local law enforcement and elected officials, such as the Governor. Limit all unnecessary travel.

Snow and blizzards can occur without notice. An emergency plan should include a strategy to feed and house employees stuck at the facility. The plan should address whether the employee is inside or outside. It should also address the potential for no heat in the facility due to power outages, etc.

Power Outages

Power outages can result in damaged equipment. For this reason, the security plan must address the procedures to follow to manage the event until the power has been restored, including shutdown procedures. The contact numbers for all utilities should be included in the emergency response plan, such as electrical, gas, and water utilities.

Chemical Spills

Depending on the size of the chemical spill, the incident may be managed by an in-house chemical spill cleanup team. The spill cleanup team must be trained in proper cleanup and disposal procedures. Pre-staging of spill cleanup kits should be conducted at the most likely source of the spill.

Active Shooter

It seems that the active shooter scenario is becoming more and more frequent. Many employers are divided in their thinking on the response procedures. For example, an active shooter may call in a bomb threat hoping that employees exit the building, while they remain outside and take shots at the exiting employees. The overwhelming majority of employers and law enforcement. recommend one of the following three actions:

- Run
- Hide
- Fight

Running is probably the best option if there is a clear and safe escape route. When this is not possible, it is best to get to a safe location and hide. Remember to turn off or silence all cell phones. Turn off lights and lock the door, if possible. Most importantly, stay quiet until law enforcement personnel arrive. If you have an opportunity to contact law enforcement, provide your name and location. Follow the directions of the law enforcement. While difficult to do in frightening situations, do not place repeated calls to law enforcement, as they will be busy during this time. Finally, fighting should happen only as a last resort. Weapons can be manufactured from various items. For example,

a chair, coffee pot, or other items may be used. If fighting is necessary, fight with all your effort as your life depends on it. When police arrive, approach with your hands in the air and follow their directions exactly. They are on high alert and do not know the shooter's identity.

Media Events

In the event of a major emergency, there will undoubtedly be newspaper and television reporters surrounding the place. The plan should address to whom all requests for information should be referred. The last thing a company needs in an emergency is to hear five (5) different accounts on the local news. Employees should also be trained to avoid talking with the media and to whom to direct all contact.

Workplace Violence Prevention

The first step in preventing workplace violence is the implementation of programs to identify potential risks of workplace violence and to implement corrective measures. The requirement to have a workplace violence prevention program lies in the OSH Act's General Duty Clause, §5(a)(1). It requires employers to provide their employees with a workplace free from recognized hazards. OSHA defines workplace violence as physical assault, threatening behavior, or verbal abuse occurring in the work environment.[3] One area that presents itself as a high-risk industry is late-night retail establishments, such as convenience stores, gasoline stations, and liquor stores. Another major area of concern regarding workplace violence is disgruntled employees who have been terminated. In 2017, workplace violence accounted for 807 work-related fatalities.

Workplace violence prevention programs should establish a clear policy for workplace violence and ensure that no worker who reports or experiences workplace violence faces reprisal. In addition, the program should encourage workers to promptly report incidents and suggest ways to reduce or eliminate risks. The program should also include a comprehensive plan for maintaining security in the workplace and assign responsibility and authority for the program to individuals with appropriate training and skills. The four elements of any good workplace violence prevention program include:[4]

- Management leadership and worker involvement
- Worksite analysis
- Safety and health training
- Hazard prevention and control

Management leadership and commitment complement worker involvement and are essential to the overall effectiveness of the safety and health system, including workplace violence prevention. Management must provide both

financial and human resources to support an active workplace violence prevention program. Employee involvement requires that employees are trained in workplace violence prevention policies, follow the rules, and participate in improving the program through suggestions. Employees can also be helpful in reporting violent incidents and by participating in safety committees to improve the safety and health conditions present in the facility.[5]

Worksite analysis involves an initial and periodic assessment to identify environmental, operational, and physical threats that may be present. In addition, records of incidents may also assist in determining potential risks. At a minimum, an annual formal review of the worksite analysis should be conducted.

Safety and health training, specifically in Workplace Violence Prevention, should be presented to all new employees at the new hire orientation. In addition, this training should be conducted periodically, at least annually, to keep it current.

Hazard and prevention controls include the training of employees in emergency response procedures, physical barriers to prevent unauthorized facility entrance, and the development of procedures. Control measures must be continuously evaluated to ensure their effectiveness in preventing incidents of workplace violence. Other prevention measures have been previously discussed in terms of physical security controls.

Key Information to Remember Regarding Site Security

A Site Security Plan must be developed to protect employees, equipment, property, and inventory, especially those mandated by the Department of Homeland Security.

1. The plan should include the site information, such as the name, physical address, contact numbers, products and services provided by the facility, number of employees, operating hours, site area description, neighborhood description, and areas of high-risk concern.
2. Management must be committed to providing the necessary human and financial resources to ensure the successful implementation of the plan.
3. Facility Access Control is one of the most important aspects of any physical security plan.
4. A means to identify visitors and contractors should be included in the site security plan.
5. When using the 911 alert system, a person should be designated (by position) to meet the emergency responders and direct them to the specific location of the emergency.

6. When dealing with a bomb threat, collect as much information on the caller or the situation as possible and write it down immediately.
7. In an active shooter scenario, the options are to run, hide, or fight.
8. Additionally, in an active shooter scenario, follow all directions from law enforcement personnel exactly.
9. Employees should be trained to observe and report incidents of workplace violence immediately. This helps employers prevent potential threats to employees.

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33

Sustainability and Sustainability Principles

What Is Sustainability?

According to the United States Environmental Protection Agency (USEPA), sustainability is based on the principle that everything needed for survival is either directly or indirectly, based on our natural environment.[2] In simple terms, sustainability means that one has the ability to meet present needs while, at the same time, not compromising the ability of future generations to meet their own. Sustainability may include environmental, economic, and social dimensions.

Sustainability in the United States is based, in part, on the National Environmental Policy Act of 1969, which committed the United States to a national policy to "create and maintain conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations."[2] Since the establishment of this national policy, the public's interest in sustainability has increased substantially.

Sustainable Development

The United Nations defined sustainable development. as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.[3] Sustainable development. and sustainable principles are not new concepts. However, they have gained new attention in recent years, as people and corporations have begun to look to the future. Sustainability goals are to create and maintain conditions under which humans and nature can exist in productive harmony that permit fulfilling the social, economic, and other requirements of present and future generations. These goals were outlined in the National Environmental Policy Act of 1969. The interconnections between the three principles are demonstrated in Figure 33.1.

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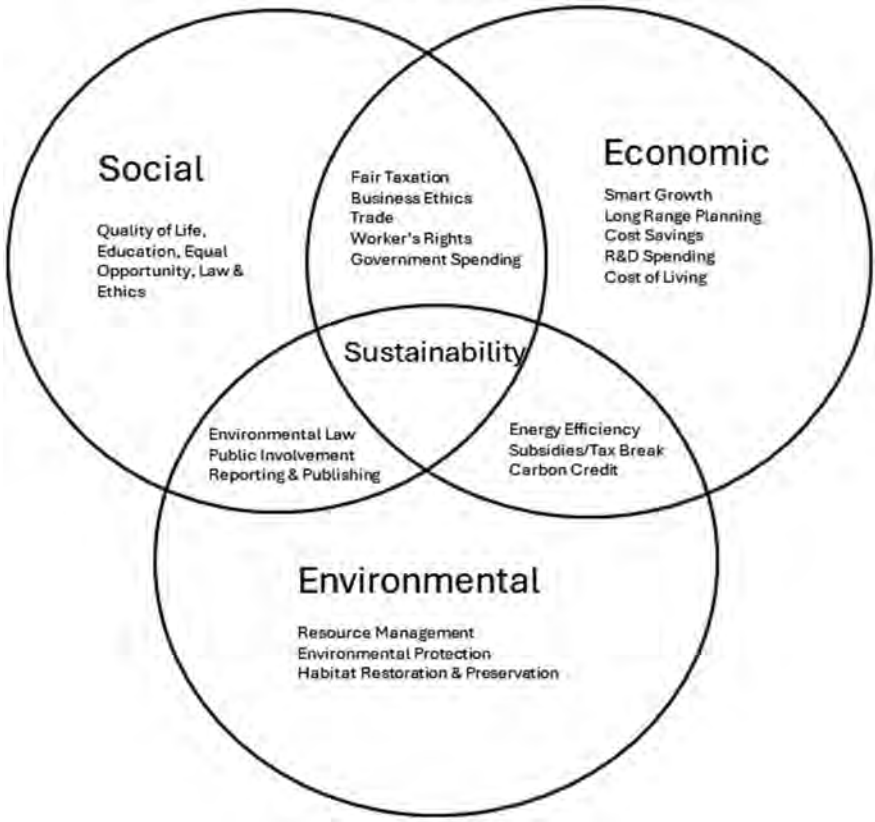


FIGURE 33.1
Sustainability principles model.[4]

There are five principles of sustainable development that include:[4]

- Conservation of the ecosystem and the environment
- Conservation of the biodiversity of the planet
- Sustainable development of society
- Conservation of human resources
- Population control and management

Conservation of the Ecosystem and the Environment

It should go without saying, but the conservation of the ecosystem and the environment is vital for maintaining the health and well-being of the planet. The ecosystem provides essential aspects required to support life, which include clean air, water, soil, and climate regulation. By conserving each of

these natural systems, sustainability of resources is ensured.. When discussing ecosystems, one of the first things that come to mind is the protection of biodiversity.

The environmental domain includes several interconnected areas, including:

- Energy
  1. Air quality
  2. Water quality
- Materials
- Biodiversity

Energy is concerned with the proper use and type of energy that do not compromise the environment and include systems and technologies that reduce or prevent pollution to the air and water quality. Materials include the reduction or elimination of waste and waste products. Biodiversity encourages a balance of species in the environment, protection of ecosystems, and the restoration of natural habitats.

Conservation of the Biodiversity of the Planet

The conservation of the biodiversity of plants involves the protection and management of biodiversity to obtain resources for sustainable development..[5] It refers to the variability of life on earth and can be conserved through in-situ and ex-situ conservation methods.

In-situ concerns the practice of protecting ecosystems, species, and genetic diversity in their natural habitats. By preserving the natural environment, this method of conservation allows species to have a natural interaction with their surroundings, which fosters adaptation and resilience in the face of environmental changes.

In-situ conservation involves the establishment of protected areas such as national parks, wildlife reserves, and marine sanctuaries. By protecting these areas, the species are provided a haven where they are safe from human activities, including deforestation, hunting, and the encroaching urbanization of areas. Management of these habitats enhances their suitability for preserving native species. For instance, restoration projects are designed to rehabilitate degraded ecosystems, control invasive species, and reintroduce native species that have been reduced or lost. To be successful, these areas require community involvement. Training, education, and communication with the public is critical to a successful project. By maintaining natural habitats, in-situ biodiversity conservation ensures the survival of species and the health of the ecosystems.

Ex-situ conservation is a strategy by conservationists that involves protecting endangered species by removing them or part of them from a population and placing them in a new, more controlled environment. Typically, this type of conservation method is employed after in-situ methods have failed or have not been as effective at maintaining desired levels. This often occurs when the natural habitat is destroyed through human activity (i.e., logging operations) or by natural disasters.

Some examples of ex-situ conservation are through the establishment of botanical gardens, zoos, aquariums, and more recently, seed banks. By establishing these environments, conservationists seek to create places where endangered species can not only survive but thrive. Ex-situ conservation is an indispensable tool that safeguards biodiversity.

Sustainable Development of Society

To have a sustainable society involves a holistic approach that includes economic growth, social inclusion, and environmental stewardship. This holistic approach aims to meet present needs while at the same time not compromising the ability of future generations to meet their needs as well.

The development of a sustainable society requires the promotion of more efficient activities and systems. Green technologies and renewable energy sources are critical to a sustainable society and include wind, solar, and water that reduce society's reliance on non-renewable sources such as fossil fuels, which increase the likelihood of climate change impacts. In addition, society requires investments in sustainable infrastructure and green jobs, which can stimulate economic growth that fosters the conservation of the environment.

Another topic of today's sustainable efforts focuses on diversity, equity, and inclusion. At its core, diversity, equity, and inclusion (DEI) is intended to ensure that the economic benefits are more fairly distributed to marginalized groups, including gender and race. The primary focus of this effort is to reduce poverty, enhance education, and ensure access to healthcare by empowering all segments of society.

Sustainable development is not a single-faceted approach but a multi-faceted one that requires collaborative efforts across all sectors and disciplines. By prioritizing long-range goals over short-term gains, societies can achieve a harmonious balance that supports enduring prosperity, social well-being, and environmental health.

Some of the elements of a sustainable community include, but are not limited to, the following[6]:

- Equal opportunities for all individuals to participate in and influence decisions
- Adequate access to public information
- A diverse and financially viable economic base

- Reinvestment of resources into the local economy
- Maximization of local ownership of businesses
- Meaningful employment opportunities for all citizens
- A reliable food supply that optimizes local production
- Adequate health services, safe and healthy housing, and high-quality education for all members of the community

In conclusion, the sustainable development of society can enhance the quality of life by strengthening internal structures, such as those listed here.

Conservation of Human Resources

In addition to the development of a sustainable society is the conservation of human resources. Conservation of human resources is not a new concept. In 1894, Milton S. Hershey founded Hershey Chocolate Company, which has become one of, if not, the leading chocolate manufacturing companies in the world. He took significant pride in his work, but more importantly, his community. Mr Hershey learned early in the 1900s the value of goods and services, and the philosophy resonated through every idea he had. His belief was that nothing should go to waste. This same philosophy led him to look at the manufacturing process. He found that the cocoa bean hulls could be ground up and used for mulch or sold to tobacco manufacturers to be used as cigar fillers. He once saw a candy wrapper thrown on the ground with the blank side up. He had the idea that this space could be used for advertising products. This concept resulted in additional income from advertisers of various products. In addition to his waste reduction activities, Mr Hershey looked at the treatment of his employees as precious resources and therefore initiated a program whereby he would provide all utility services free of charge (electric, water, sewer). His philosophy in this area was that if he took care of the employees, they would, in turn, take care of his business. Mr Hershey also built a model community where the employees had access to good public schools, churches, parks, a zoo, and even a trolley system as public transportation.[7]

In the conservation of human resources, the basis lies with humans as the pivotal determinant for sustainable development.. For today's safety professional, this aspect is reflected in the focus on occupational safety and health as part of this human capital or conservation concept.

Population Control and Management

Population control and management is one of the most controversial topics discussed today, even among environmentalists. The controversy does not necessarily revolve around the concept but the methods. Many see population control and management as critical to limit the strain on the

environment and resources. Others see it as an intrusive burden placed on the human population by bureaucrats and politicians. An example of the controversy arose when China implemented the one-child policy. While this policy may have had desired consequences, there were some unintended results that stemmed from it. The first issue from this policy was that many families, desiring to carry on family lines through a male heir, elected to terminate pregnancies of female offspring. A more concerning issue for the Chinese government was that the policy was so effective that it resulted in not enough workers to support the economy at desired levels in later years. The one-child policy was modified in 2015 to allow families to have two children. While the modification was welcomed by families, the Chinese government continues to play a deeply intrusive role in women's reproductive choices by controlling both the number of children a couple can have and the intervals in which they may have them.[8]

Now that an explanation of the varying perspectives has been discussed, the idea of population control and management can be discussed. Some form of population control and management appears to be inevitable over time. Effective population control involves policies and practices designed to stabilize or reduce population growth rates to ensure sustainable development.. The focus of these policies includes family planning, education, and government policies that promote smaller family sizes. Keep in mind that many years ago (early American) and in other countries revolved around agriculture where there was a heavy labor requirement. Families were purposely large to supply farm workers to support the family.

A key aspect of population control is the availability and accessibility of contraceptives that empower individuals to make informed choices about reproduction. In addition to contraceptives, education plays a critical role in maintaining lower fertility rates. Educated women tend to marry later and have fewer children, which contributes to slower population growth. Another aspect of population control and management, as has already been mentioned, is government policies that influence population growth. While China's one-child policy came with ethical controversies, other policies, such as those from Sweden, support properly planning through comprehensive sex education and healthcare services.

Population management goes beyond measuring mere numbers, but addresses the distribution and composition of the population. Urban planning, healthcare infrastructure, and economic policies must adapt to the demographic changes to mitigate potential negative impacts on society and the environment.

Ultimately, ethical considerations and human rights must guide any discussion or policies regarding population control and management by respecting individual freedoms while promoting the collective well-being of society. Balancing these aspects is essential for achieving sustainable development. and a stable global population.

Triple Bottom Line Theory

The Triple Bottom Line Theory demonstrates that sustainability is based on the three (3) P's. The three P's include:

- People
- Profit
- Planet

The Triple Bottom Line Theory is represented graphically in Figure 33.2 below.

The sustainability "movement" began as environmental sustainability but has now expanded into other phases and is often referred to as "Corporate Social Responsibility." Looking to improve all three areas makes good business sense and ultimately will lead to improved profits, a healthier planet, and a better quality of life for people.

It is, or should be, clearly understood that the purpose of any company or corporation is to make a profit. They are not incorporated to create jobs or anything else. With that being said, businesses are becoming increasingly aware that being good stewards of the environment is not only an ethical requirement but is also critical in sustaining their future business opportunities, which are outlined in the Triple Bottom Line (TBL) Theory.



FIGURE 33.2
Triple Bottom Line Theory.

People

A company following the Triple Bottom Line Theory will maintain a philosophy that its employees are part of the wider community in which the company operates. A company that invests in Triple Bottom Line methods will pay fair wages and ensure that its employees work under humane conditions. These companies place great value on the contributions of their employees. Furthermore, these companies support the local communities through various means, such as supporting youth sports, contributing to the local fire and police departments, etc.

Profit

While profits are generally measured in financial terms, TBL companies recognize their impact on people and the planet as being just as important. These companies have realized that in many cases, investing in people and the environment significantly shows positive financial impacts on the company's bottom line. This is primarily because customers prefer to support companies that invest in these activities.

Planet

TBL companies will include environmental stewardship in their profit plans and operating costs. In addition, these companies often show trends toward investing in renewable sources and decreasing waste. By continuously improving their pollution prevention programs, companies will also show an increase in their profit margins.

Benefits of Sustainable Development (Economic Domain)

In terms of business, sustainable development creates growth, new markets, brand loyalty, and reduced business risk and uncertainty. Sustainability reduces losses by decreasing costs, waste, energy, raw materials, and natural resources.. In addition, sustainability builds stability and trust in employees, the supply chain, customers, stakeholders, and the community. Corporate sustainability brings organizations healthy people, safer workplaces, reduced costs and accidents, controlled environments, managed risks, and improved safety knowledge. Some examples of new market developments include plant-based beverage bottles, recycled and compostable packaging, and reusable grocery bags, just to name a few. Examples of organizations and products that profit from sustainability principles include healthy fast foods, green energy, Five-Star crash ratings, hybrid cars, green cosmetics,

green buildings and shredded tires being used for other purposes, such as mulch or artificial turf. Corporations profit from sustainability by having healthy people, safer workplaces, reduced accidents, managed risks, and improved safety knowledge.

Key Performance Indicators

While there are no formally established key performance indicators (KPIs), the Global Reporting Initiative (GRI 403) Occupational Health and Safety Standard recognizes the right to a safe and healthy workplace as a human rights issue. Under the GRI 403 Standard for Occupational Health and Safety, organizations are required at a minimum to describe their approach to preventing and mitigating significant negative occupational health and safety impacts and the related hazards and risks. The disclosures required by this standard include the following[9]:

- How the organization manages occupational health and safety
- Hazard identification, risk assessment, and incident investigation
- A description of occupational health services' functions that contribute to the identification and elimination of hazards and the minimization of risk
- Description of processes for worker participation and consultation
- Description of any occupational health and safety training provided to workers
- Workers' access to non-occupational medical and healthcare services and the scope of access provided
- Description of the organization's approach to preventing or mitigating significant negative occupational health and safety impacts that are directly linked to its operations, products, or services by its business relationships and the related hazards and risks

Key Information to Remember on Sustainability and Sustainability Principles

1. Sustainability is based on the principle that everything needed for survival is either directly or indirectly, based on our natural environment.

2. Sustainability goals are to create and maintain conditions under which humans and nature can exist in productive harmony that permit fulfilling the social, economic, and other requirements of present and future generations.
3. Three major focus areas of sustainability include Social, Economic, and Environmental.
4. The ecosystem provides essential aspects required to support life, which include clean air, water, soil, and climate regulation. By conserving each of these natural systems, sustainability of resources is ensured.
5. The conservation of the biodiversity of plants involves the protection and management of biodiversity to obtain resources for sustainable development.
6. The primary focus of diversity, equity, and inclusion is to reduce poverty, enhance education, and ensure access to healthcare by empowering all segments of society.
7. To have a sustainable society involves a holistic approach that includes economic growth, social inclusion, and environmental stewardship.
8. In the conservation of human resources, the basis lies with humans as the pivotal determinant for sustainable development..
9. A key aspect of population control is the availability and accessibility to contraceptives that empower individuals to make informed choices about reproduction.
10. The elements of the Triple Bottom Line theory include people, planet and profit.
11. Sustainability reduces losses by decreasing costs, waste, energy, raw materials, and natural resources.
12. While there are no formally established key performance indicators (KPIs), the Global Reporting Initiative (GRI 403) Occupational Health and Safety Standard recognizes the right to a safe and healthy workplace as a human rights issue.

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Environmental Management

As a safety professional or future safety professional reading this book, you may be wondering what "Environmental Management" has to do with safety. It has been my experience that these two disciplines have as much in common as they are different. Therefore, I've included this chapter as an introduction on environmental management by having a working knowledge of many of the main environmental regulations.

History and Evolution of US Environmental Policies

This chapter begins with a discussion on the history and evolution of US environmental policies. This history will begin in 1970, when formal laws were passed that are directly attributable to the protection of the environment. However, just to be clear, this is not the beginning of the environmental or conservation movement, which began almost 100 years prior to this.

The National Environmental Policy Act (NEPA) (42 U.S.C. 4321)[1]

The National Environmental Policy Act (NEPA) was the beginning of modern-day environmental policies within the United States. It was signed into law on January 1, 1970, by President Richard M. Nixon. The Act establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and provides a process for implementing these goals within the federal agencies. The Act also establishes the Council on Environmental Quality (CEQ).

NEPA Requirements

Title I of NEPA contains a Declaration of National Environmental Policy that requires the federal government to use all practicable means to create and maintain conditions under which man and nature can exist in productive harmony. Section 102 requires federal agencies to incorporate environmental

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considerations in their planning and decision-making through a systematic, interdisciplinary approach. Specifically, all federal agencies are to prepare detailed statements assessing the environmental impact of, and alternatives to, major federal actions significantly affecting the environment. These statements are commonly referred to as environmental impact statements (EISs). Title II of NEPA establishes the CEQ.

Oversight of NEPA

The CEQ, which is headed by a full-time Chair, oversees NEPA. A staff assists the Council. The duties and functions of the Council are listed in Title II, Section 204 of NEPA and include the following:

- Gathering information on the conditions and trends in environmental quality
- Evaluating federal programs in light of the goals established in Title I of the Act
- Developing and promoting national policies to improve environmental quality
- Conducting studies, surveys, research, and analyses relating to ecosystems and environmental quality

Implementation

In 1978, CEQ promulgated regulations (40 CFR Parts 1500–1508) implementing NEPA, which are binding on all federal agencies. The regulations address the procedural provisions of NEPA and the administration of the NEPA process, including the preparation of EISs. To date, the only change in the NEPA regulations occurred on May 27, 1986, when CEQ amended Section 1502.22 of its regulations to clarify how agencies are to carry out their environmental evaluations in situations where information is incomplete or unavailable.

CEQ has also issued guidance on various aspects of the regulations, including an information document on "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act," Scoping Guidance, and Guidance Regarding NEPA Regulations. Additionally, most federal agencies have promulgated their own NEPA regulations and guidance, which generally follow the CEQ procedures but are tailored for the specific mission and activities of the agency.

The NEPA Process

The NEPA process consists of an evaluation of the environmental effects of a federal undertaking including its alternatives. There are three levels of analysis: categorical exclusion determination, preparation of an environmental assessment/finding of no significant impact (EA/FONSI), and preparation of an EIS.

- *Categorical exclusion*: At the first level, an undertaking may be categorically excluded from a detailed environmental analysis if it meets certain criteria that a federal agency has previously determined as having no significant environmental impact. A number of agencies have developed lists of actions that are normally categorically excluded from environmental evaluation under their NEPA regulations.
- *EA/FONSI*: At the second level of analysis, a federal agency prepares a written EA to determine whether or not a federal undertaking would significantly affect the environment. If the answer is no, the agency issues a FONSI. The FONSI may address measures that an agency will take to mitigate potentially significant impacts.
- *EIS*: If the EA determines that the environmental consequences of a proposed federal undertaking may be significant, an EIS is prepared. An EIS is a more detailed evaluation of the proposed action and alternatives. The public, other federal agencies, and outside parties may provide input into the preparation of an EIS and then comment on the draft EIS when it is completed.

If a federal agency anticipates that an undertaking may significantly affect the environment, or if a project is environmentally controversial, the federal agency may choose to prepare an EIS without having to first prepare an EA.

After a final EIS is prepared and at the time of its decision, a federal agency will prepare a public record of its decision, addressing how the findings of the EIS, including consideration of alternatives, were incorporated into the agency's decision-making process.

EAs and EIS Components

An EA is described in Section 1508.9 of the CEQ NEPA regulations. Generally, an EA includes brief discussions of the following:

- The need for the proposal
- Alternatives (when there is an unresolved conflict concerning alternative uses of available resources)
- The environmental impacts of the proposed action and alternatives
- A listing of agencies and persons consulted

An EIS, which is described in Part 1502 of the regulations, should include the following:

- Discussions of the purpose of and need for the action
- Alternatives
- The affected environment
- The environmental consequences of the proposed action

- Lists of preparers, agencies, organizations, and persons to whom the statement is sent
- An index
- An appendix (if any)

Federal Agency Role

The role of a federal agency in the NEPA process depends on the agency's expertise and relationship to the proposed undertaking. The agency carrying out the federal action is responsible for complying with the requirements of NEPA.

- *Lead agency*: In some cases, there may be more than one federal agency involved in an undertaking. In this situation, a lead agency is designated to supervise the preparation of the environmental analysis. Federal agencies, together with state, tribal, or local agencies, may act as joint lead agencies.
- *Cooperating agency*: A federal, state, tribal, or local agency having special expertise with respect to an environmental issue or jurisdiction by law may be a cooperating agency in the NEPA process. A cooperating agency has the responsibility to assist the lead agency by participating in the NEPA process at the earliest possible time; by participating in the scoping process; in developing information and preparing environmental analyses, including portions of the EIS concerning which the cooperating agency has special expertise; and in making available staff support at the lead agency's request to enhance the lead agency's interdisciplinary capabilities.
- *CEQ*: Under Section 1504 of CEQ's NEPA regulations, federal agencies may refer to CEQ on interagency disagreements concerning proposed federal actions that might cause unsatisfactory environmental effects. CEQ's role, when it accepts a referral, is generally to develop findings and recommendations, consistent with the policy goals of Section 101 of NEPA.

Environmental Protection Agency's Role

The Environmental Protection Agency (EPA), like other federal agencies, prepares and reviews NEPA documents. However, the EPA has a unique responsibility in the NEPA review process. Under Section 309 of the Clean Air Act (CAA), the EPA is required to review and publicly comment on the environmental impacts of major federal actions, including actions that are the subject of EISs. If the EPA determines that the action is environmentally unsatisfactory, it is required by Section 309 to refer the matter to CEQ.

In accordance with a Memorandum of Agreement between EPA and CEQ, EPA carries out the operational duties associated with the administrative aspects of the EIS filing process. The Office of Federal Activities in EPA has

been designated as the official recipient in EPA of all EISs prepared by federal agencies.

The Public's Role

The public has an important role in the NEPA process, particularly during scoping, in providing input on what issues should be addressed in an EIS and in commenting on the findings in an agency's NEPA documents. The public can participate in the NEPA process by attending NEPA-related hearings or public meetings and by submitting comments directly to the lead agency. The lead agency must take into consideration all comments received from the public and other parties on NEPA documents during the comment period.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act—commonly referred to as RCRA—is our nation's primary law governing the disposal of solid and hazardous waste. Congress passed RCRA on October 21, 1976, to address the increasing problems the nation faced from our growing volume of municipal and industrial waste. RCRA, which amended the Solid Waste Disposal Act of 1965, set national goals for

- Protecting human health and the environment from the potential hazards of waste disposal
- Conserving energy and natural resources
- Reducing the amount of waste generated
- Ensuring that wastes are managed in an environmentally sound manner

To achieve these goals, RCRA established three distinct, yet interrelated, programs:

- The solid waste program, under RCRA Subtitle D, encourages states to develop comprehensive plans to manage nonhazardous industrial solid waste and municipal solid waste (MSW), sets criteria for MSW landfills and other solid waste disposal facilities, and prohibits the open dumping of solid waste.
- The hazardous waste program under RCRA Subtitle C establishes a system for controlling hazardous waste from the time it is generated until its ultimate disposal—in effect, from "cradle to grave."
- The underground storage tank (UST) program, under RCRA Subtitle I, regulates USTs containing hazardous substances and petroleum products.

RCRA banned all open dumping of waste, encouraged source reduction and recycling, and promoted the safe disposal of municipal waste. RCRA also mandated strict controls over the treatment, storage, and disposal of hazardous waste. The first RCRA regulations, "Hazardous Waste and Consolidated Permit Regulations," published in the Federal Register on May 19, 1980 (45 FR 33066; May 19, 1980), established the basic "cradle to grave" approach to hazardous waste management that exists today.

RCRA was amended and strengthened by Congress in November 1984 with the passing of the Federal Hazardous and Solid Waste Amendments (HSWA). These amendments to RCRA required phasing out land disposal of hazardous waste. Some of the other mandates of this strict law include increased enforcement authority for the EPA, more stringent hazardous waste management standards, and a comprehensive UST program.

RCRA has been amended on two occasions since HSWA:

1. Federal Facility Compliance Act of 1992—strengthened enforcement of RCRA at Federal facilities.
2. Land Disposal Program Flexibility Act of 1996 (5 pp, 24 kB)—provided regulatory flexibility for land disposal of certain wastes.

RCRA focuses only on active and future facilities and does not address abandoned or historical sites that are managed under the Comprehensive Environmental Response, Compensation, and Liability Act—commonly known as Superfund.[2]

Regulations promulgated pursuant to Subtitle C of RCRA (40 CFR Parts 260–299) establish a "cradle-to-grave" system governing hazardous waste from the point of generation to disposal. RCRA hazardous wastes include the specific materials listed in the regulations (commercial chemical products, designated with the code "P" or "U"; hazardous wastes from specific industries/sources, designated with the code "K"; hazardous wastes from nonspecific sources, designated with the code "F") and materials that exhibit a hazardous waste characteristic (ignitability, corrosivity, reactivity, or toxicity) designated with the code "D."

Regulated entities that generate hazardous waste are subject to waste accumulation, manifesting, and recordkeeping standards. Facilities that treat, store, or dispose of hazardous waste must obtain a permit, either from the EPA or from a state agency that the EPA has authorized to implement the permitting program. Subtitle C permits contain general facility standards such as contingency plans, emergency procedures, recordkeeping and reporting requirements, financial assurance mechanisms, and unit-specific standards. RCRA also contains provisions (40 CFR Part 264 Subpart S and Part 264.10) for conducting corrective actions that govern the cleanup of releases of hazardous waste or constituents from solid waste management units at RCRA-regulated facilities.

Although RCRA is a federal statute, many states implement the RCRA program. Currently, EPA has delegated its authority to implement various provisions of RCRA to 46 of the 50 states.

Most RCRA requirements are not industry-specific but apply to any company that generates, transports, treats, stores, or disposes of hazardous waste. Here are some important RCRA regulatory requirements:

- Solid waste and hazardous waste
- Universal waste
- Used oil management standards
- USTs

Solid Waste and Hazardous Waste[3]

Solid waste means any garbage or refuse; sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility; and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities. Solid wastes include both hazardous and nonhazardous waste.

A waste may be considered hazardous if it is ignitable (i.e., burns readily), corrosive, or reactive (e.g., explosive). Waste may also be considered hazardous if it contains certain amounts of toxic chemicals. In addition to these characteristic wastes, the EPA has also developed a list of more than 500 specific hazardous wastes. Hazardous waste takes many physical forms and may be solid, semisolid, or even liquid.

Acute hazardous wastes contain such dangerous chemicals that they could pose a threat to human health and the environment even when properly managed. These wastes are fatal to humans and animals even in low doses.

Subtitle C of the RCRA creates a cradle-to-grave management system for hazardous waste to ensure proper treatment, storage, and disposal in a manner that is protective of human health and the environment.

Identification of Solid and Hazardous Wastes

This regulation (40 CFR Part 261) lays out the procedure every generator should follow to determine whether the material created is considered hazardous waste, solid waste or is exempted from regulation.

Standards for Generators of Hazardous Waste

This regulation (40 CFR Part 262) establishes the responsibilities of hazardous waste generators, including obtaining an identification number, preparing a manifest, ensuring proper packaging and labeling, meeting standards

for waste accumulation units, and recordkeeping and reporting requirements. Generators can accumulate hazardous waste for up to 90 days (or 180 days depending on the amount of waste generated) without obtaining a permit for being a treatment, storage, and disposal (TSD) facility.

Land Disposal Restrictions

Land disposal restrictions (LDRs) are regulations prohibiting the disposal of hazardous waste on land without prior treatment. Under 40 CFR 268, materials must meet treatment standards before placement in an RCRA land disposal unit (landfill, land treatment unit, waste pile, or surface impoundment). Wastes subject to the LDR include solvents, electroplating wastes, heavy metals, and acids. Generators of waste subject to these restrictions must notify the designated TSD facility to ensure proper treatment before disposal.

Tanks and Containers

Tanks and containers used to store hazardous waste with a high volatile organic concentration must meet emission standards under RCRA. Regulations (40 CFR Parts 264 and 265, Subpart CC) require generators to test the waste to determine the concentration of the waste, to satisfy tank and container emissions standards, and to inspect and monitor regulated units. These regulations apply to all facilities that store such waste, including generators operating under the 90-day accumulation rule.

Hazardous Waste and Agriculture

Irrigation return flows are not considered hazardous waste. Agricultural producers disposing of waste pesticides from their own use are exempt from hazardous waste requirements as long as (1) they triple-rinse the emptied containers in accordance with the labeling to facilitate the removal of the chemical from the container, and (2) they dispose of the pesticide residue on their own agricultural establishment in a manner consistent with the disposal instructions on the pesticide label.

Disposal of hazardous waste on an agricultural establishment could subject the agricultural producer to significant responsibility, including closure and post-closure care. Offsite disposal of hazardous waste could subject agricultural producers to hazardous waste generator requirements.

Universal Waste[3]

The universal waste rule is designed to reduce the number of hazardous waste items in the MSW stream, encourage recycling and proper disposal of certain common hazardous wastes, and reduce the regulatory burden

on businesses that generate these wastes. Universal wastes include the following:

- *Batteries* such as nickel–cadmium (Ni–Cd) and small sealed lead-acid batteries are found in many common items in business and home settings, including electronic equipment, mobile telephones, portable computers, and emergency backup lighting.
- *Agricultural pesticides* that have been recalled or banned from use are obsolete, have become damaged, or are no longer needed because of changes in cropping patterns or other factors. They are often are stored for long periods in sheds or barns.
- *Thermostats,* which can contain as much as 3 g of liquid mercury, are in almost any building, including commercial, industrial, agricultural, community, and household buildings.

Universal wastes are generated by small and large businesses that are regulated under RCRA and have been required to handle these materials as hazardous wastes. The universal waste rule eases the regulatory burden on businesses that generate these wastes. Specifically, it streamlines the requirements related to notification, labeling, marking, prohibitions, accumulation time limits, employee training, response to releases, offsite shipments, tracking, exports, and transportation. For example, the rule extends the amount of time that businesses can accumulate these materials on-site. It also allows companies to transport them with a common carrier, instead of a hazardous waste transporter, and no longer requires companies to obtain a manifest.

Universal Waste and Agriculture

The universal waste rule does not apply to businesses (such as many agricultural establishments and other agribusinesses) that generate less than 100 kg of universal waste per month (Conditionally Exempt Small Quantity Generators). The EPA encourages these businesses to participate voluntarily in collection and recycling programs by bringing these wastes to collection centers for proper treatment and disposal.

Used Oil Management Standards[3]

Used oil management standards (40 CFR Part 279) impose management requirements affecting the storage, transportation, burning, processing, and re-refining of used oil. For facilities that merely generate used oil, the regulations establish storage standards. A facility that is considered a used oil marketer (one who generates and sells off-specification used oil directly to a used oil burner) must satisfy additional tracking and paperwork requirements.

EPA's regulatory definition of used oil is as follows: Used oil is any oil (either synthetic or refined from crude oil) that has been used and, as a result of such use, is contaminated by physical or chemical impurities. Simply put, used oil is exactly what its name implies—any petroleum-based or synthetic oil that has been used. During normal use, impurities such as dirt, metal scrapings, water, or chemicals can get mixed in with the oil, so that in time, the oil no longer performs well. Eventually, this used oil must be replaced with virgin or re-refined oil to do the job at hand.

EPA's used oil management standards include a three-pronged approach to determine if a substance meets the definition of used oil. To meet EPA's definition of used oil, a substance must meet each of the following three criteria:

- *Origin*—the first criterion for identifying used oil is based on the origin of the oil. Used oil must have been refined from crude oil or made from synthetic materials. Animal and vegetable oils are excluded from the EPA's definition of used oil.
- *Use*—the second criterion is based on whether and how the oil is used. Oils used as lubricants, hydraulic fluids, heat transfer fluids, buoyants, and for other similar purposes are considered used oil. Unused oils, such as bottom clean-out waste from virgin fuel oil storage tanks or virgin fuel oil recovered from a spill, do not meet EPA's definition of used oil because these oils have never been "used." EPA's definition also excludes products used as cleaning agents or solely for their solvent properties, as well as certain petroleum-derived products like antifreeze and kerosene.
- *Contaminants*—the third criterion is based on whether or not the oil is contaminated with either physical or chemical impurities. In other words, to meet EPA's definition, used oil must become contaminated as a result of being used. This aspect of EPA's definition includes residues and contaminants generated from handling, storing, and processing used oil. Physical contaminants could include metal shavings, sawdust, or dirt. Chemical contaminants could include solvents, halogens, or saltwater.

Used Oil and Agriculture

Agricultural producers who generate an average of 25 gal or less per month from vehicles or machinery per calendar year are exempt from these regulations. Those exceeding 25 gal are required to store it in tanks meeting underground or above-ground technical requirements and use transporters with EPA authorization numbers for removal from the agricultural establishment. Storage in unlined surface impoundments (defined as wider than deep) is banned.

Underground Storage Tanks[3]

A UST system is a tank and any underground piping connected to the tank that has at least 10% of its combined volume underground. USTs containing petroleum and hazardous substances are regulated under Subtitle I of RCRA. Subtitle I regulations (40 CFR Part 280) contain tank design and release detection requirements, as well as financial responsibility and corrective action standards for USTs. The UST program also establishes increasingly stringent standards, including upgrade requirements for existing tanks, that were to be met by 1998.

In 1984, Congress responded to the increasing threat to groundwater posed by leaking USTs by adding Subtitle I to the RCRA. Subtitle I required the EPA to develop a comprehensive regulatory program for USTs storing petroleum or certain hazardous substances.

In 1986, Congress amended Subtitle I of RCRA and created the Leaking Underground Storage Tank Trust Fund and established financial responsibility requirements. Congress directed the EPA to publish regulations that would require UST owners and operators to demonstrate that they are financially capable of cleaning up releases and compensating third parties for resulting damages.

The following USTs are excluded from regulation and, therefore, do not need to meet federal requirements for USTs:

- Farm and residential tanks of 1100 gal or less capacity holding motor fuel used for noncommercial purposes
- Tanks storing heating oil used on the premises where it is stored
- Tanks on or above the floor of underground areas, such as basements or tunnels
- Septic tanks and systems for collecting stormwater and wastewater
- Flow-through process tanks
- Tanks of 110 gal or less capacity
- Emergency spill and overfill tanks

Subtitle I of RCRA allows state UST programs approved by EPA to operate in lieu of the federal program, and EPA's state program approval regulations set standards for state programs to meet. States may have more stringent regulations than the federal requirements. People who are interested in requirements for USTs should contact their state UST program for information on state requirements.

USTs and Agriculture

For agricultural establishments, USTs and their associated piping holding less than 1100 gal of motor fuel for noncommercial purposes, tanks holding

less than 110 gal, tanks holding heating oil are used on the premises, and septic tanks are excluded from regulations. All newly installed regulated USTs are required to meet regulations related to construction, monitoring, operating, reporting to state or federal regulatory agencies, owner record keeping, and financial responsibility. Requirements for regulated USTs installed before December 22, 1988, were phased in through December 2, 1989.

Toxic Substances Control Act (TSCA) (15 U.S.C. §2601 et seq.(1976))[4]

The Toxic Substances Control Act of 1976 provides the EPA with authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances or mixtures. Certain substances are generally excluded from TSCA, including, among others, food, drugs, cosmetics, and pesticides.

TSCA addresses the production, importation, use, and disposal of specific chemicals, including polychlorinated biphenyls, asbestos, radon, and lead-based paint. Various sections of TSCA provide authority to

- Require, under Section 5, premanufacture notification for "new chemical substances" before manufacture.
- Require, under Section 4, testing of chemicals by manufacturers, importers, and processors where risks or exposures of concern are found.
- Issue Significant New Use Rules, under Section 5, when it identifies a "significant new use" that could result in exposures to, or releases of, a substance of concern.
- Maintain the TSCA Inventory, under Section 8, which contains more than 83,000 chemicals. As new chemicals are commercially manufactured or imported, they are placed on the list.
- Require those importing or exporting chemicals, under Sections 12(b) and 13, to comply with certification, reporting, and other requirements.
- Require, under Section 8, reporting and record-keeping by persons who manufacture, import, process, or distribute chemical substances in commerce.
- Require, under Section 8(e), that any person who manufactures (including imports), processes, or distributes in commerce a chemical substance or mixture and who obtains information that reasonably supports the conclusion that such substance or mixture

presents a substantial risk of injury to health or the environment, to immediately inform EPA, except where EPA has been adequately informed of such information. EPA screens all TSCA b§8(e) submissions as well as voluntary "For Your Information" submissions. The latter are not required by law but are submitted by industry and public interest groups for a variety of reasons.

What Does It Mean for a Chemical to Be on the TSCA Inventory?

Substances on the TSCA Inventory are considered "existing" chemicals in US commerce, and substances not on the TSCA Inventory are considered "new" chemicals. If a substance is determined to be a "new" chemical substance for TSCA purposes, it is subject to TSCA Section 5 Premanufacture Notice (PMN) requirements, unless the substance meets a TSCA reporting exclusion (e.g., is a naturally occurring material) or is exempt from PMN reporting (e.g., is an exempted polymer). (The TSCA Inventory must be consulted to determine if a specific substance is "new" or "existing.") For substances that are "existing" chemical substances in US commerce, the TSCA Inventory can be used to determine if there are restrictions on manufacture or use.[5]

How Are Chemicals Added to the TSCA Inventory?

After PMN review has been completed, the company that submitted the PMN must provide a Notice of Commencement of Manufacture or Import (NOC) (EPA Form 7710-56) to EPA within 30 calendar days of the date the substance is first manufactured or imported for nonexempt commercial purposes. A chemical substance is considered to be on the TSCA Inventory and becomes an existing chemical as soon as a complete NOC is received by the EPA. The Agency receives between 500 and 1000 NOCs each year; thus, the TSCA Inventory changes daily.

Non-PMN submissions (Low Volume Exemptions, Low Release/Low Exposure Exemptions, and Test Market Exemptions) and exempt uses not subject to submission (R&D) do not require a NOC and are not listed on the TSCA Inventory.[5]

How to Get a Determination from EPA on Whether a Chemical Is on the Inventory?

If an intended manufacturer or importer of a chemical substance is unsure of the TSCA Inventory status of the chemical (e.g., cannot find that substance on one of the public sources of nonconfidential TSCA Inventory data), the company or representative can obtain a written determination from the EPA if it can demonstrate a "genuine intent." It can do this by submitting a Bona Fide Intent to Manufacture or Import Notice pursuant to the procedures at 40 CFR Section 720.25.[5]

Bona Fide Intent to Manufacture or Import Notice

In a bona fide notice, a submitter must

- Provide specific chemical identification data, including the Chemical Abstracts Index name, as well as information about the substances' manufacture or importation. Proper CA Index names can be obtained from the Chemical Abstracts Service's Inventory Expert Service.
- Possibly submit a letter of support (see below). This may be necessary if some information is withheld from the submitter by, for example, a supplier.
- Certify intent to manufacture or import the intended substance for a commercial purpose.
- Provide all the other information required in support of a bona fide notice.

In some cases, a potential manufacturer may intend to use reactants whose specific chemical identities are held confidential by their suppliers. In certain other cases, a potential importer may intend to bring into the United States a substance whose identity is known only to its foreign manufacturer. In these cases, a letter of support from the domestic or foreign manufacturer of the confidential substances can be provided directly to the EPA and should include specific chemical identity information. When using a Branded Material of Confidential Composition, users will need information from their suppliers to ensure that they are and remain in compliance.

Instructions on Notices of Bona Fide Intent to Manufacture are available from the TSCA hotline.[5]

Letter of Support

Specific chemical identity information is required for Bona Fide Intent to Manufacture or Import Notices, PMNs, and other purposes under TSCA. The EPA must be notified of any confidential chemical identity information (e.g., a reactant only known by a trade name is used in the manufacture of a chemical substance that is the subject of a bona fide notice or PMN). Information that has been withheld from the submitter by a third party should be submitted directly to the EPA by that third party (e.g., usually a domestic or foreign supplier or manufacturer). In its letter of support, the third party must provide chemical identity information for the confidential substance as specified in the amended regulation at 40 CFR Section 720.45(a).

If confidential substances are involved and require a third-party letter of support, a bona fide notice or PMN submitter must keep in mind that all supporting material must be received by the EPA for a bona fide notice or PMN to be considered complete. A submitter should also have an agreement with

its supplier to ensure being informed of any changes in composition that can change the chemical identity of the confidential substance.[5]

Branded Materials of Confidential Composition

Manufacturers and importers whose reportable substances are manufactured with branded materials that have confidential components should take steps to be informed in a timely manner if the branded materials change in composition. EPA does not use brand names in listing substances on the TSCA Inventory, in part because branded material formulations can change and in part because the TSCA Inventory identifies and lists specific chemical substances and not formulations.[5]

Federal Insecticide, Fungicide, and Rodenticide Act

The objective of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is to provide federal control of pesticide distribution, sale, and use. All pesticides used in the United States must be registered (licensed) by the EPA. Registration assures that pesticides will be properly labeled and that, if used in accordance with specifications, they will not cause unreasonable harm to the environment. Use of each registered pesticide must be consistent with the use directions contained on the label or labeling.

The first pesticide control law was enacted in 1910. This law was primarily aimed at protecting consumers from ineffective products and deceptive labeling. When the FIFRA was first passed in 1947, it established procedures for registering pesticides with the US Department of Agriculture and established labeling provisions. The law was still, however, primarily concerned with the efficacy of pesticides and did not regulate pesticide use.

FIFRA was essentially rewritten in 1972 when it was amended by the Federal Environmental Pesticide Control Act (FEPCA). The law has been amended numerous times since 1972, including some significant amendments in the form of the Food Quality Protection Act of 1996. In its current form, FIFRA mandates that the EPA regulate the use and sale of pesticides to protect human health and preserve the environment.

Since the FEPCA amendments, the EPA is specifically authorized to (1) strengthen the registration process by shifting the burden of proof to the chemical manufacturer, (2) enforce compliance against banned and unregistered products, and (3) promulgate the regulatory framework missing from the original law.

FIFRA provides EPA with the authority to oversee the sale and use of pesticides. However, because FIFRA does not fully preempt state/tribal or local law, each state/tribe and local government may also regulate pesticide use.[6]

Tolerances and Exemptions

Before the EPA can register a pesticide that is used on raw agricultural products, it must grant a tolerance or exemption. Tolerance is the maximum amount of a pesticide that can be on a raw product when it is used and still be considered safe. Under the Food, Drug, and Cosmetic Act (FDCA), a raw agricultural product is deemed unsafe if it contains a pesticide residue, unless the residue is within the limits of a tolerance established by the EPA or is exempt from the requirement. The FDCA requires the EPA to establish these residue tolerances.[6]

Tolerances and Agriculture

Food or feed residues that lack tolerances or have residues exceeding the established tolerances are subject to seizure, and the applicators or agricultural producers are subject to prosecution under FIFRA if misuse is found.[6]

Registration of New Pesticides

Under FIFRA Section 3, all new pesticides (with minor exceptions) used in the United States must be registered by the Administrator of the EPA. Pesticide registration is very specific; it is not valid for all uses of a particular chemical. Each registration specifies the crops/sites on which it may be applied, and each use must be supported by research data. Ordinarily, the manufacturer (domestic or foreign) of the pesticide files an application for registration. The application process often requires the submission of extensive environmental, health, and safety data.

Conditional registration may be given to some new pesticides while the EPA obtains the data needed to make a full analysis of the product. After a pesticide is registered, the registrant must also notify the EPA of any newly uncovered facts concerning adverse environmental effects (FIFRA Section 6(a)(2)). In addition, the EPA is required to periodically review pesticide registrations, with a goal of review every 15 years. Variations of the registration requirements exist for "minor use pesticides," "antimicrobial pesticides," and "reduced risk pesticides."

Data Requirements for Registration

The categories of data required include the product's chemistry, environmental fate, residue chemistry, dietary and non-dietary hazards to humans, and hazards to domestic animals and non-target organisms (40 CFR Part 158).

Under the "product chemistry" category, applicants must supply technical information describing the product's active and inert ingredients, manufacturing or formulating processes, and physical and chemical characteristics.

Data from "environmental fate" studies are used to assess the effects of pesticide residues on the environment, including the effect on nontarget organisms and their habitat. Residue chemistry information includes the expected frequency, amounts, and time of application, and test results of residue remaining on treated food or feed.

Information under "hazards to humans, domestic animals, and nontarget organisms" includes specific test data assessing acute, subchronic, and chronic toxicity; skin and eye irritation potential; and potential exposure by various routes (i.e., oral, dermal, or inhalation).

All studies must be conducted under conditions that meet Good Laboratory Practice standards (40 CFR Part 160). Guidelines for studies of product chemistry, residue chemistry, environmental chemistry, hazard evaluation, and occupational and residential exposure can be found in 40 CFR Part 158.

Registration Criteria

To register a pesticide, the Administrator must find the following to be true:

- Its composition is such as to warrant the proposed claims for it.
- Its labeling and other material required to be submitted comply with the requirements of the Act.
- It will perform its intended function without unreasonable adverse effects on the environment.
- When used in accordance with widespread and commonly recognized practice, it will not generally cause unreasonable adverse effects on the environment.

Unreasonable Adverse Effects on the Environment

FIFRA defines an "unreasonable adverse effect on the environment" as "(1) any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of the pesticide, or (2) a human dietary risk from residues that result from the use of a pesticide in or on any food inconsistent with the standard under Section 408 of the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 346a)."

Clean Air Act of 1970 (42 U.S.C. §7401 et seq. (1970))

The CAA is the comprehensive federal law that regulates air emissions from stationary and mobile sources. Among other things, this law authorizes the EPA to establish National Ambient Air Quality Standards (NAAQS) to

protect public health and public welfare and to regulate emissions of hazardous air pollutants.

One of the goals of the Act was to set and achieve NAAQS in every state by 1975 in order to address the public health and welfare risks posed by certain widespread air pollutants. The setting of these pollutant standards was coupled with directing the states to develop state implementation plans (SIPs), applicable to appropriate industrial sources in the state, in order to achieve these standards. The Act was amended in 1977 and 1990 primarily to set new goals (dates) for achieving attainment of NAAQS since many areas of the country had failed to meet the deadlines.

Section 112 of the CAA addresses emissions of hazardous air pollutants. Prior to 1990, CAA established a risk-based program under which only a few standards were developed. The 1990 CAA Amendments revised Section 112 to first require the issuance of technology-based standards for major sources and certain area sources. "Major sources" are defined as a stationary source or group of stationary sources that emit or have the potential to emit 10 tons per year or more of a hazardous air pollutant or 25 tons per year or more of a combination of hazardous air pollutants. An "area source" is any stationary source that is not a major source.

For major sources, Section 112 requires that the EPA establish emission standards that require the maximum degree of reduction in emissions of hazardous air pollutants. These emission standards are commonly referred to as "maximum achievable control technology" or "MACT" standards. Eight years after the technology-based MACT standards are issued for a source category, the EPA is required to review those standards to determine whether any residual risk exists for that source category and, if necessary, revise the standards to address such risk.[7]

Clean Air Act of 1990[8]

In June 1989, President Bush proposed sweeping revisions to the CAA. Building on Congressional proposals advanced during the 1980s, the President proposed legislation designed to curb three major threats to the nation's environment and the health of millions of Americans: acid rain, urban air pollution, and toxic air emissions. The proposal also called for establishing a national permits program to make the law more workable and an improved enforcement program to help ensure better compliance with the Act.

By large votes, both the House of Representatives (401–21) and the Senate (89–11) passed Clean Air bills that contained the major components of the President's proposals. Both bills also added provisions requiring the phase-out of ozone-depleting chemicals, roughly according to the schedule outlined

in international negotiations (Revised Montreal Protocol). The Senate and House bills also added specific research and development provisions, as well as detailed programs to address accidental releases of toxic air pollutants.

A joint conference committee met from July to October 1990 to iron out differences in the bills, and both Houses overwhelmingly voted out the package recommended by the Conferees. The President received the Bill from Congress on November 14, 1990, and signed it on November 15, 1990.

Several progressive and creative new themes are embodied in the Amendments; themes necessary for effectively achieving the air quality goals and regulatory reform expected from these far-reaching amendments. Specifically, the new law

- Encourages the use of market-based principles and other innovative approaches, like performance-based standards and emission banking and trading.
- Provides a framework from which alternative clean fuels will be used by setting standards in the fleet and California pilot programs that can be met by the most cost-effective combination of fuels and technology.
- Promotes the use of clean, low-sulfur coal and natural gas, as well as innovative technologies to clean high-sulfur coal through the acid rain program.
- Reduces enough energy waste and creates enough of a market for clean fuels derived from grain and natural gas to cut dependency on oil imports by one million barrels per day.
- Promotes energy conservation through an acid rain program. that gives utilities flexibility to obtain needed emission reductions through programs that encourage customers to conserve energy.

With these themes providing the framework for the CAA amendments and with our commitment to implementing the new law quickly, fairly, and efficiently, Americans will get what they asked for: a healthy, productive environment, linked to sustainable economic growth and sound energy policy.

Title I: Provisions for Attainment and Maintenance of NAAQS

Although the CAA of 1977 brought about significant improvements in our nation's air quality, the urban air pollution problems of ozone (smog), carbon monoxide (CO), and particulate matter (PM-10) persist. Currently, over 100 million Americans live in cities that are out of attainment with the public health standards for ozone.

The most widespread and persistent urban pollution problem is ozone. The causes of this and the lesser problem of carbon monoxide (CO) and particulate matter (PM-10) pollution in our urban areas are largely attributed to

the diversity and number of urban air pollution sources. One component of urban smog—hydrocarbons—comes from automobile emissions, petroleum refineries, chemical plants, dry cleaners, gasoline stations, house painting, and printing shops. Another key component—nitrogen oxides—comes from the combustion of fuel for transportation, utilities, and industries.

While there are other reasons for continued high levels of ozone pollution, such as the growth in the number of stationary sources of hydrocarbons and the continued growth in automobile travel, perhaps the most telling reason is that the remaining sources of hydrocarbons are also the most difficult to control. These are the small sources—generally those that emit less than 100 tons of hydrocarbons per year. These sources, such as auto body shops and dry cleaners, may individually emit less than 10 tons per year, but collectively emit many hundreds of tons of pollution.

The CAA Amendments of 1990 create a new, balanced strategy for the nation to attack the problem of urban smog. Overall, the new law reveals Congress' high expectations of the states and the federal government. While it gives states more time to meet the air quality standard—up to 20 years for ozone in Los Angeles—it also requires states to make constant formidable progress in reducing emissions. It requires the federal government to reduce emissions from cars, trucks, and buses; from consumer products such as hair spray and window washing compounds; and from ships and barges during the loading and unloading of petroleum products. The federal government must also develop the technical guidance that states need to control stationary sources.

The new law addresses the urban air pollution problems of ozone (smog), carbon monoxide (CO), and particulate matter (PM-10). Specifically, it clarifies how areas are designated and redesignated as "attainment." It also allows the EPA to define the boundaries of "nonattainment" areas: geographical areas whose air quality does not meet federal air quality standards designed to protect public health.

The new law also establishes provisions defining when and how the federal government can impose sanctions on areas of the country that have not met certain conditions. For the pollutant ozone, the new law establishes nonattainment area classifications ranked according to the severity of the area's air pollution problem. These classifications are marginal, moderate, serious, severe, and extreme. The EPA assigns each nonattainment area one of these categories, thus triggering varying requirements the area must comply with in order to meet the ozone standard.

As mentioned, nonattainment areas will have to implement different control measures, depending on their classification. Marginal areas, for example, are the closest to meeting the standard. They will be required to conduct an inventory of their ozone-causing emissions and institute a permit program. Nonattainment areas with more serious air quality problems must implement various control measures. The worse the air quality, the more controls these areas will have to implement.

The new law also establishes similar programs for areas that do not meet the federal health standards for the pollutants carbon monoxide and particulate matter. Areas exceeding the standards for these pollutants will be divided into "moderate" and "serious" classifications. Depending upon the degree to which they exceed the carbon monoxide standard, areas will be required to implement programs introducing oxygenated fuels and enhanced emission inspection programs, among other measures. Depending on their classification, areas exceeding the particulate matter standard will have to implement either reasonably available control measures or best available control measures, among other requirements.

Title II: Provisions Relating to Mobile Sources

While motor vehicles built today emit fewer pollutants (60% to 80% less, depending on the pollutant) than those built in the 1960s, cars and trucks still account for almost half the emissions of the ozone precursors VOCs and NOx, and up to 90% of the CO emissions in urban areas. The principal reason for this problem is the rapid growth in the number of vehicles on the roadways and the total miles driven. This growth has offset a large portion of the emission reductions gained from motor vehicle controls.

In view of the unforeseen growth in automobile emissions in urban areas, combined with the serious air pollution problems in many urban areas, Congress has made significant changes to the motor vehicle provisions of the 1977 CAA.

The CAA of 1990 establishes tighter pollution standards for emissions from automobiles and trucks. These standards will reduce tailpipe emissions of hydrocarbons, carbon monoxide, and nitrogen oxides on a phased-in basis beginning in model year 1994. Automobile manufacturers will also be required to reduce vehicle emissions resulting from the evaporation of gasoline during refueling.

Title III: Air Toxics

Toxic air pollutants are those pollutants that are hazardous to human health or the environment but are not specifically covered under another portion of the CAA. These pollutants are typically carcinogens, mutagens, and reproductive toxins. The CAA Amendments of 1977 failed to result in substantial reductions in the emissions of these very threatening substances. In fact, over the history of the air toxics program, only seven pollutants have been regulated.

We know that the toxic air pollution problem is widespread. Information generated from the Superfund "Right to Know" rule (SARA Section 313) indicates that more than 2.7 billion pounds of toxic air pollutants are emitted annually in the United States. EPA studies indicate that exposure to such quantities of air toxics may result in 1000 to 3000 cancer deaths each year.

The CAA of 1990 offers a comprehensive plan for achieving significant reductions in emissions of hazardous air pollutants from major sources. Industry reports in 1987 suggest that an estimated 2.7 billion pounds of toxic air pollutants were emitted into the atmosphere, contributing to approximately 300–1500 cancer fatalities annually. The new law will improve the EPA's ability to address this problem effectively, and it will dramatically accelerate progress in controlling major toxic air pollutants.

The new law includes a list of 189 toxic air pollutants whose emissions must be reduced. The EPA must publish a list of source categories that emit certain levels of these pollutants within 1 year after the new law is passed. The list of source categories must include (1) major sources emitting 10 tons per year of any one, or 25 tons per year of any combination of those pollutants; and (2) area sources (smaller sources, such as dry cleaners).

EPA then must issue MACT standards for each listed source category according to a prescribed schedule. These standards will be based on the best demonstrated control technology or practices within the regulated industry, and EPA must issue the standards for 40 source categories within 2 years of passage of the new law. The remaining source categories will be controlled according to a schedule that ensures all controls will be achieved within 10 years of enactment. Companies that voluntarily reduce emissions according to certain conditions can get a 6-year extension from meeting the MACT requirements.

Eight years after MACT is installed on a source, the EPA must examine the risk levels remaining at the regulated facilities and determine whether additional controls are necessary to reduce unacceptable residual risk.

The new law also establishes a Chemical Safety Board to investigate accidental releases of chemicals. Furthermore, the new law requires the EPA to issue regulations controlling air emissions from municipal, hospital, and other commercial and industrial incinerators.

Title IV: Acid Deposition Control

As many know, acid rain occurs when sulfur dioxide and nitrogen oxide emissions are transformed in the atmosphere and return to the earth in rain, fog, or snow. Approximately 20 million tons of SO_2 are emitted annually in the United States, mostly from the burning of fossil fuels by electric utilities. Acid rain damages lakes, harms forests and buildings, contributes to reduced visibility, and is suspected of damaging health.

The new law also includes specific requirements for reducing emissions of nitrogen oxides, based on EPA regulations to be issued not later than mid-1992 for certain boilers and 1997 for all remaining boilers.

Title V: Permits

The new law introduces an operating permits program modeled after a similar program under the Federal National Pollution Discharge Elimination

Discharge System law. The purpose of the operating permits program is to ensure compliance with all applicable requirements of the CAA and to enhance the EPA's ability to enforce the Act. Air pollution sources subject to the program must obtain an operating permit, states must develop and implement the program, and the EPA must issue permit program regulations, review each state's proposed program, and oversee the state's efforts to implement any approved program. The EPA must also develop and implement a federal permit program when a state fails to adopt and implement its own program.

This program—in many ways the most important procedural reform contained in the new law—will greatly strengthen enforcement of the CAA. It will enhance air quality control in a variety of ways. First, adding such a program updates the CAA, making it more consistent with other environmental statutes. The Clean Water Act, the RCRA, and the FIFRA all require permits. The 1977 Clean Air laws also require a construction permit for certain pollution sources, and about 35 states have their own laws requiring operating permits.

The new program clarifies and makes more enforceable a source's pollution control requirements. Currently, a source's pollution control obligations may be scattered throughout numerous hard-to-find provisions of state and federal regulations, and in many cases, the source is not required under the applicable SIP to submit periodic compliance reports to the EPA or the states. The permit program will ensure that all of a source's obligations with respect to its pollutants are contained in one permit document and that the source will file periodic reports identifying the extent to which it has complied with those obligations. Both of these requirements will greatly enhance the ability of federal and state agencies to evaluate the air quality situation.

In addition, the new program will provide a ready vehicle for states to assume administration, subject to federal oversight, of significant parts of the air toxics program and the acid rain program., and, through the permit fee provisions required under Title V, the program will greatly augment a state's resources to administer pollution control programs by requiring sources of pollution to pay their fair share of the costs of a state's air pollution program.

Under the new law, the EPA must issue program regulations within 1 year of enactment. Within 3 years of enactment, each state must submit to the EPA a permit program meeting these regulatory requirements. After receiving the state submission, the EPA has 1 year to accept or reject the program. The EPA must levy sanctions against a state that does not submit or enforce a permit program.

Each permit issued to a facility will be for a fixed term of up to 5 years. The new law establishes a permit fee whereby the state collects a fee from the permitted facility to cover the reasonable direct and indirect costs of the permitting program.

All sources subject to the permit program must submit a complete permit application within 12 months of the effective date of the program. The state

permitting authority must determine whether or not to approve an application within 18 months of the date it receives the application.

EPA has 45 days to review each permit and to object to permits that violate the CAA. If EPA fails to object to a permit that violates the Act or the implementation plan, any person may petition EPA to object within 60 days following EPA's 45-day review period, and EPA must grant or deny the petition within 60 days. Judicial review of EPA's decision on a citizen's petition can occur in the federal court of appeals.

Title VI: Stratospheric Ozone and Global Climate Protection

The new law builds on the market-based structure and requirements currently contained in EPA's regulations to phase out the production of substances that deplete the ozone layer. The law requires a complete phaseout of CFCs and halons, with interim reductions and some related changes to the existing Montreal Protocol, revised in June 1990.

Under these provisions, the EPA must list all regulated substances along with their ozone depletion potential, atmospheric lifetimes, and global warming potentials within 60 days of enactment.

In addition, the EPA must ensure that Class I chemicals are phased out on a schedule similar to that specified in the Montreal Protocol—CFCs, halons, and carbon tetrachloride by 2000; methyl chloroform by 2002—but with more stringent interim reductions. Class II chemicals (hydrochlorofluorocarbons) will be phased out by 2030. Regulations for Class I chemicals will be required within 10 months, and Class II chemical regulations were required by December 31, 1999.

The law also requires the EPA to publish a list of safe and unsafe substitutes for Class I and II chemicals and to ban the use of unsafe substitutes. The law requires nonessential products releasing Class I chemicals to be banned within 2 years of enactment. In 1994, a ban went into effect for aerosols and non-insulating foams using Class II chemicals, with exemptions for flammability and safety. Regulations for this purpose will be required within 1 year of enactment, to become effective 2 years afterward.

Title VII: Provisions Relating to Enforcement

The CAA of 1990 contains a broad array of authorities to make the law more readily enforceable, thus bringing it up to date with the other major environmental statutes. The EPA has new authorities to issue administrative penalty orders up to $200,000 and field citations up to $5,000 for lesser infractions. Civil judicial penalties are enhanced. Criminal penalties for knowing violations are upgraded from misdemeanors to felonies, and new criminal authorities for knowing and negligent endangerment will be established.

In addition, sources must certify their compliance, and the EPA has authority to issue administrative subpoenas for compliance data. The EPA will also

be authorized to issue compliance orders with compliance schedules of up to 1 year.

The citizen suit provisions have also been revised to allow citizens to seek penalties against violators, with the penalties going to a US Treasury fund for use by the EPA for compliance and enforcement activities. The government's right to intervene is clarified, and citizen plaintiffs will be required to provide the United States with copies of pleadings and draft settlements.

Other Titles

The CAA Amendments of 1990 continue the federal acid rain research program and contain several new provisions relating to research, development, and air monitoring. They also contain provisions to provide additional unemployment benefits through the Job Training Partnership Act to workers laid off because of compliance with the CAA. The Act also contains provisions to improve visibility near National Parks and other parts of the country.

ISO 14001

No discussion of environmental management would be complete without mentioning ISO 14001. However, this discussion within the confines of this chapter will be limited to a basic overview. A detailed discussion on ISO 14001 was included in Chapter 31. ISO 14001, as mentioned previously, is the internationally accepted standard that sets out the requirements for an environmental management system.

Key Points to Remember on Environmental Management

1. The National Environmental Protection Act (NEPA) was signed into law on January 1, 1970. Its major focus was to require the federal government to use all practicable means to create and maintain conditions under which man and nature can exist in productive harmony.
2. NEPA specifically requires all federal agencies to prepare detailed environmental impact statements (EISs) that assess the environmental impact of, and alternatives to, major federal actions significantly affecting the environment.
3. NEPA establishes the Council on Environmental Quality (CEQ), which is specifically appointed to oversee the provisions of NEPA.
4. The Resource Conservation and Recovery Act (RCRA) is the primary policy of the United States governing the disposal of solid and hazardous wastes.

5. RCRA specifically covers solid and hazardous waste, universal waste, used oil management, and underground storage tanks.
6. Solid waste means any garbage or refuse; sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility; and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities. Solid wastes include both hazardous and nonhazardous waste.
7. Universal wastes include items such as batteries, agricultural pesticides, and thermostats.
8. The Toxic Substances Control Act (TSCA) provides EPA with the authority to require reporting, recordkeeping and testing requirements, and restrictions relating to chemical substances and mixtures.
9. The purpose of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) is to provide federal control of pesticide distribution, sale, and use.
10. The Clean Air Act of 1990 was designed to curb three major threats to the nation's environment, including acid rain, urban air pollution, and toxic air emissions.

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35

Prevention through Design (PtD)

It almost goes without saying, but the most effective means of controlling occupational injuries and illnesses is to eliminate the hazards that cause the injuries and illnesses. To eliminate the hazard before they even become a hazard is the focus of the Prevention through Design principle. Prevention through Design (PtD) is a concept with its focus on designing out or the minimization of hazards and risks. The National Institute of Occupational Safety and Health (NIOSH) leads this National initiative to promote this concept and to further highlight its importance in all business decisions.[1]

Primary Goal of PtD

The primary purpose of this initiative is, of course, to prevent or reduce occupational injuries, illnesses, and fatalities by including prevention considerations that impact workers in the design or redesign phase of projects.[1] If a potential hazard is identified early in the process, it can be engineered out and never become an actual hazard. A couple of actual examples that have occurred in the redesign phase are as follows:

A. A process in a biofuel facility required monthly cleaning using high-pressure vacuum systems. Part of the process required employees to climb 300 feet of stairs carrying heavy vacuum hoses that would be dropped over the railings to the vacuum truck. This posed a significant slip, trip, and fall hazard, as well as various ergonomic strains. During the redesign review, this was addressed, and the solution resulted in a simple "standpipe" and connection ports installation on all levels. As a result, the employees now only had to carry about 15–20 ft of hose versus the 300-plus feet. The hazard was significantly reduced.
B. A mining operation required an employee to climb the exterior ladder of a silo twice daily to check a gauge that was located on top of the silo. During an operational "shutdown" design review, the potential hazard associated with the climbing activity was reviewed. A simple redesign resulted in the gauge being lowered to ground level, thus eliminating the climbing activity.

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Both above examples are illustrative of the purpose and benefits of a Prevention through Design program.

Benefits of Prevention through Design (PtD)

There are numerous benefits to a mature Prevention through Design (PtD) program. Some of these benefits include:

- Always maintaining acceptable risk levels
- The overall enhanced well-being of employees
- Enhanced job satisfaction
- Human performance productivity
- Direct cost savings for companies

PtD Assessment Timeframes

There are three primary timeframes to implement PtD activities. They include:

- Pre-Operational mode
- Operation mode
- Post-incident mode

Pre-Operational Mode

The pre-operational mode is where the opportunities are the greatest, and the costs are lower for hazard and risk avoidance, elimination, and control.

Operational Mode

During the operational mode of the phase, hazards can be eliminated or controlled, and therefore, the risks reduced before their potential effects are realized and the hazard-related incidents or exposures occur.

Post-Incident Mode

During this phase, an incident has occurred, presenting the opportunity to during the investigation to determine causal factors and provide not only corrective measures but preventive measures.

Definitions

Before delving into the larger topic, a list of terms and definitions is presented.

Prevention through Design

Prevention through Design can be defined as the practice of addressing safety and health needs in the design and redesign process to prevent or minimize the work-related hazards and risks associated with the construction, manufacturing, use, maintenance, retrofitting, and disposal of a facility's processes, materials, and equipment.[2]

Acceptable Risk

The risk at which level has been reduced in both probability and severity to the lowest level reasonably possible for the conditions and environment in which it is being considered.

ALARP

ALARP is an acronym that stands for "As Low As Reasonably Practicable" and is very similar to ALARA, which represents "As Low As Reasonably Achievable."

Design

The process of transforming an idea into detailed specifications whereby it can be produced. The Merriam-Webster Dictionary defines "design" as "to create, fashion, execute, or construct according to plan; to conceive and plan out in the mind; to have as a purpose for a specific function".[3]

Hazard

Any condition or action that has the potential to cause harm.

Hazard Analysis

A hazard analysis is the process that is initiated with the recognition of a hazard, then proceeds to an estimate of the severity of harm or damage that could result.

Hierarchy of Controls

A systematic way of thinking and acting with consideration of steps in a ranked and sequential order to choose the most effective means. For purposes of this chapter, the American National Standards Institute (ANSI Z590.3) Hierarchy of Controls Model will be used, which consists of Avoidance, Elimination, Substitution, Engineering Controls, Warnings, Administrative Controls, and Personal Protective Equipment (PPE), which are ranked in order from most effective to least effective. This is represented graphically in Figure 35.1 .

Life cycle: The complete phases of the facility, equipment, material, and processes, including design, construction, operation, maintenance, and disposal.
Probability: It is the likelihood that a given event will occur.[4]
Residual risk: The risk that remains after the preventive measures have been implemented. It must be pointed out that there will always be some measure of risk, no matter how effective the preventive actions are.
Risk: It is an estimate of the probability and severity of a hazard-related incident or exposure occurring.
Risk assessment: It is the process of assessing the risks posed by identified hazards in order to make decisions and implement appropriate control measures to prevent the hazard from occurring.[4]
Risk avoidance: It is the mitigation of a hazard by removing the exposure that may cause harm.
Severity: It is the degree of undesired consequences.[4]
Safety: The condition or state where the risks are at an acceptable level for the environment being considered.

Significant Milestones for Prevention through Design (PtD)

The following is a guideline of major milestones regarding PtD:

- 1994—The American Society of Safety Engineers (now the American Society of Safety Professionals) released a position paper to promote the gathering of information, knowledge, and applications of designing for safety concepts.
- National Safety Council

FIGURE 35.1
ANSI hierarchy of controls (Source: Yates, W. David 2024).

1. 1995—Established the Institute for Safety through Design.
2. 1999—Institute published Safety through Design, which was instrumental in the current PtD concept.

- 2007—The National Institute of Occupational Safety and Health (NIOSH) launched the Prevention through Design (PtD) Initiative. The purpose was to develop concepts for designing out or minimizing hazards and risks.
- 2007—American National Standards Institute (ANSI) released a technical report on PtD, which led to the first United States Standard on this concept (ANSI/ASSE 590.3–2011 (R2016)

It has been established that there is a strong correlation between workplace design and fatalities. As such, the focus on PtD activities has significantly increased in recent years within the United States, Australia, the United Kingdom and other countries as a means to reduce injuries and fatalities.

PtD Assessment Periods/Stages

It has already been mentioned earlier in this chapter that there are key timeframes for assessment, which include pre-operational mode, operational mode, and post-Incident mode. This is further discussed below and includes:

- Pre-design stage
- Conceptual stage
- Design stage
- Build or purchase stage
- Installation, construction, and setup stage
- Operational stage
- Decommission stage

These stages are illustrated graphically in Figure 35.2.

Pre-Design Stage

During the pre-design stage, the safety objectives and identification of potential risks are established. It involves understanding of the parameters for the design to operate by gathering data on similar existing systems and consulting with key stakeholders, which may include safety professionals

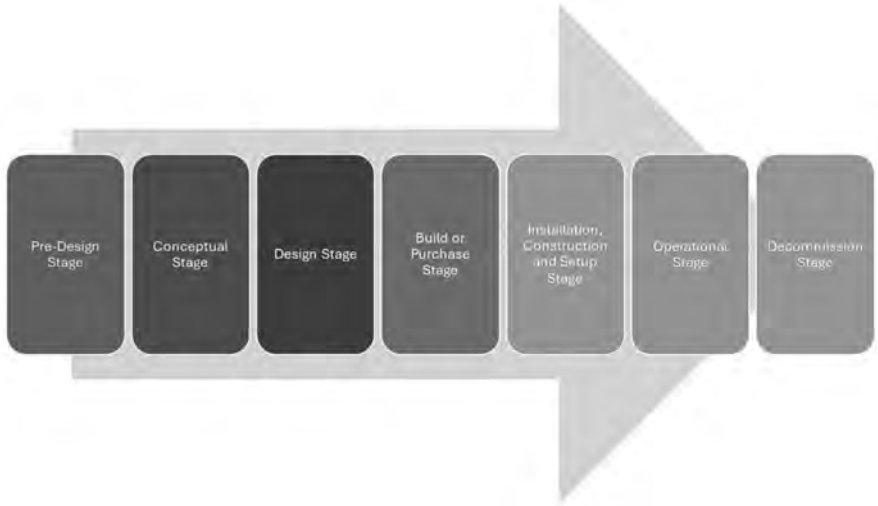


FIGURE 35.2
Assessment timeframes for prevention through design (PtD) (Source: Yates, W. David 2024).

and engineers. During the pre-design stage, risk assessments are conducted for the environments and tasks that will be performed to predict foreseeable hazards. By conducting these risk assessments, the goal is to reduce or eliminate any exposure to potential hazards. This reduction is based on the Hierarchy of Controls.

Conceptual Stage

The next step in the process involves the conceptual design stage, where various design options are considered with safety being a central element. A common tactic during this stage is the use of brainstorming sessions, conducting feasibility studies, and reviewing preliminary risk assessments. The project designers may also use various techniques and tools in this evaluation to determine the safest and most effective solutions. Tools used during this process may include Failure Modes and Effects Analysis (FMEA) or Hazard and Operability Study (HAZOP) to assess the potential failure points and operational risks. The overall aim is to eliminate hazards or reduce their impact before the actual detailed design begins.

Design Stage

In the design stage, the results and ideas of the pre-design and conceptual stages are refined, and details are added to ensure the most effective means of control. During this stage, detailed drawings and specifications are prepared. Specific safety features that were identified in the conceptual stage are incorporated into the detailed design. Prior to implementation, and included

within this stage, is the safety testing and simulations that are conducted to make sure that the design meets the established criteria. Remember, the premise of the PtD program is to reduce the number of hazards and risks associated with work in order to eliminate or minimize them. Finally, compliance with relevant safety standards and regulations is reviewed during this stage.

Build or Purchase Stage

During the build or purchase stage, designed materials, equipment, or supplies are purchased or built. Attention to detail at this stage is critical to ensure that they meet or exceed established specifications. For example, a specification design may call for a material that will carry a static load of 35,000 pounds. If the materials purchased to build that design are incapable of supporting this load, then the system has the potential to fail. Another major focus during this stage is to choose equipment with built-in safety features that are less harmful and can significantly reduce workplace hazards, such as a robotic assembly that would eliminate the potential for ergonomic strains.

Installation, Construction, and Setup Stage

While each of the stages is important, the installation, construction, and setup stage is where the planning and building actually come into existence. It is where a project is both visually seen and felt. During this stage, it is crucial that the plan is closely followed to achieve the desired results of reducing injuries and incidents. For the safety professional, it is a time that deserves close attention in the actual construction and setup by focusing on the safety of employees doing the actual construction. This focus will involve following relevant policies and procedures, wearing appropriate personal protective equipment, and conducting daily risk assessments to ensure any hazards are appropriately identified and corrected in a timely manner.

Operational Stage

Once all previous stages have been completed, the project enters the operational stage. It is during this stage that there is a focus on maintaining safe working conditions throughout the life of the equipment or system. During the operational stage, the safety professional can focus on the following to ensure the continued safety of personnel:

- Enforcement of established safety procedures and protocols.
- Proper training of employees.

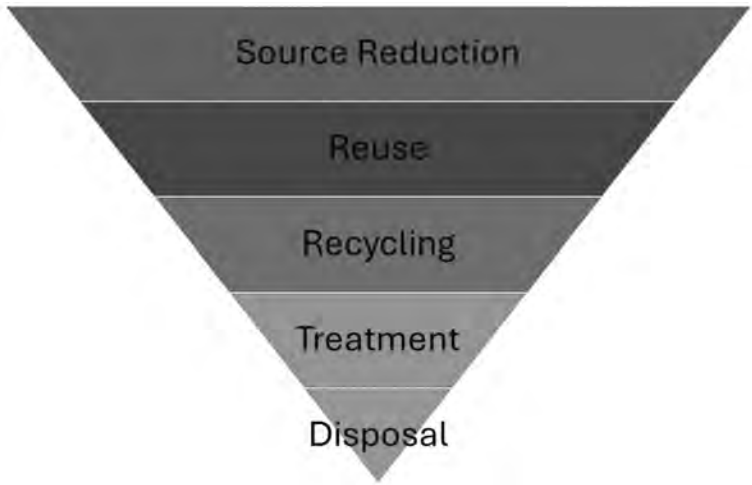


FIGURE 35.3
Pollution prevention hierarchy of controls (Source: Yates, W. David 2024).

- Correct PPE is issued and worn.
- Conducting routine and periodic inspections.
- Routinely request (and listen to) employee feedback on concerns. By doing so, management can gain valuable insight into potential risks that were previously not accounted for.

Decommission Stage

The decommission stage is the final period in a system's "life." This stage involves the disassembling and disposal of obsolete equipment and machinery. Just as in the pre-design stage of a project, the decommissioning stage involves careful and diligent planning to ensure the safety and health of employees. Proper decommissioning procedures help prevent injuries, illnesses, and even environmental contamination. By implementing the pollution prevention hierarchy of controls, the environmental risks can be reduced. This hierarchy of control for pollution prevention is shown graphically in Figure 35.3.

PtD Process

The actual process of Prevention through Design (PtD) follows the sample steps in the risk management process, which include the following:

- Establish risk criteria
- Form a qualified team
- Identification of hazards
- Risk analysis
- Risk levels compared to established criteria
- Risk treatment
- Documentation
- Monitoring
- Communication of results

In establishing risk criteria, the evaluator will provide the context, scope, and purpose of the risk assessment. Secondly, a qualified and trained team, consisting of key stakeholders and subject matter experts (SMEs), is gathered and presented with the criteria. This team of individuals will go through a process of identifying hazards through observations, information, and historical data review. In addition to identifying the hazards, the team determines the consequences of each hazard and the list of existing controls. All of these are then analyzed in detail to determine specific risk levels by evaluating the likelihood of occurrence and the severity of harm. These risk levels are then compared to the risk criteria to determine if the risk is acceptable or if they need additional treatment. Risk treatment is then selected based on the hierarchy of controls to reduce risk to an acceptable level. These risk assessments and treatments are then documented and reported to management. The treatment is continually monitored going forward, and the communication of all results is reported to management and employees.

ANSI Hierarchy of Controls

Risk Avoidance

ANSI Z590.3 places significant emphasis on incorporating safety into the design stage in order to mitigate occupational hazards. The standard further encourages risk avoidance as a primary strategy, which aims to eliminate the hazard entirely. Risk avoidance involves proactive measures implemented in the design stage to prevent exposure to any potential hazards. Risk avoidance includes selecting safer materials, purchasing and installing equipment with built-in safety features, and evaluating and eliminating activities that could cause ergonomic strains or injuries. By integrating these elements early, the need for additional protective measures is reduced, thereby creating a safer work environment.

Elimination

Elimination, as prescribed in ANSI Z590.3, involves designing out hazards whenever possible. This is a proactive approach where designers identify the potential hazards and modify their designs to remove these risks entirely. Risk avoidance, on the other hand, involves modifying processes or materials to sidestep potential hazards. An example of risk avoidance would be the substitution of a more harmful chemical with one of a lesser toxicity. Risk elimination entails completely removing the hazard from the environment. An example of risk elimination would be redesigning equipment to operate without exposed moving parts.

Substitution

Ranking third in the ANSI Z590.3 Hierarchy of Controls Model is substitution. Substitution is simply the substitution of more harmful conditions, such as chemicals, and replacing them with less harmful ones. To illustrate this purpose, a painting operation uses a water-based paint to eliminate the potential exposure to volatile organic compounds. When considering substitution as a control measure, careful consideration must be taken to ensure that no additional hazards are introduced into the operation.

Engineering Controls

Next in line of the effective controls for controlling hazards in the ANSI Z590.3 model is engineering controls. Engineering controls are a critical strategy for enhancing workplace safety by designing or modifying equipment and workspaces to reduce or eliminate hazards, thus minimizing risks to occupational employees. As with the other control measures, this process begins with a comprehensive hazard and risk assessment.

Warnings

An additional control measure identified in ANSI Z590.3 is that of "Warnings." Warnings are utilized whenever a hazard or risk cannot be eliminated or sufficiently controlled through engineering controls. Warnings may include labeling, signage, and audible or visible alarms. This form of control measure relies heavily on complete compliance with established protocols and human nature. Warnings are provided to alert employees to the hazards, which allows them to take precautionary measures to prevent injury.

To be effective, warnings must be clear, concise, and easily understandable. In addition, they must be prominently displayed and incorporate universally recognized symbols and language to ensure they can be easily understood by all workers. ***While OSHA does not require a specific language, it is necessary to provide these warnings in a language understood by a***

significant portion of the worker population. For example, if there are 800 employees working in a facility and ten percent (10%) speak only Spanish and the remaining ninety percent (90%) speak English, the warning labels should be provided in both English and Spanish.

Administrative Controls

Administrative controls are ranked as one of the least effective means of controlling hazards since they rely on employee compliance and human nature. However, administrative controls can be effective when used in combination with other control measures. Administrative controls may include activities such activities as job rotation for ergonomic risks, frequent breaks during periods of excessive heat or cold, and training to ensure awareness of specific risks. While they are not the most effective means of controlling or eliminating hazards and risks, administrative controls play a vital role in accident and injury prevention.

Personal Protective Equipment

Personal protective equipment (PPE) is identified by ANSI Z590.3 and NIOSH as the least effective means of controlling occupational hazards. Personal protective equipment may include such items as hardhats, safety-toed boots, cut-resistant gloves, safety glasses, and specialty equipment. The PtD concept includes PPE as a line of defense as part of an integrated strategy for reducing risks. For example, in a metal fabricating facility, the metal poses sharp edges and, as such engineering controls are hard to implement, if not impossible. Therefore, the employer must take action to reduce lacerations from the sharp edges. They do so by providing both cut-resistant gloves and sleeves, as well as implementing a training program and warnings to identify the hazards.

Methods and Tools of Risk Assessment and Management

Preliminary Hazard Analysis (PHA)

Preliminary Hazard Analysis (PHA) is a primary feature of system safety that is used to identify and categorize hazards or potential hazards of a specific operation.. It is a technique that is used early in a process that allows risk levels to be prioritized for additional assessment and management. It is used to describe hazards that might arise from defects and unsafe conditions in

the design and operation of the system. It is useful in providing an analysis of current state risk levels and the risk reduction levels of proposed risk treatments.

What-If Analysis

What-if analysis is a team-based qualitative method that is used to identify and analyze hazards, hazard scenarios, existing controls, and needed additional controls. It was first developed in the 1960s by the British chemical industry as an easier, less costly measure like Hazard Operability (HAZOP). The main objective of this method is to identify and analyze exposure scenarios by looking at causes, weaknesses, and deviations that can lead to hazards and the needed controls to achieve an acceptable level.

Hazard and Operability Study (HAZOP)

The Hazard and Operability Study (HAZOP) is a qualitative method used to identify both hazards and operability problems. It uses guide words to prompt team members to identify deviations that can lead to failures. Examples of guide words include "no or not," "more," "less," "high," and "low."[5] The steps included in this method are:

- Build a HAZOP team.
- Identify processes, process/piping, and instrumentation diagram, and HAZOP nodes (sections in the entire process).
- Define the parameters, determine deviations, and select guide words.
- Identify controls and establish safety monitoring.
- Communicate HAZOP results and improve processes.

Failure Modes Effect Analysis (FMEA)

Failure Modes Effect Analysis (FMEA) is a detailed qualitative or semi-qualitative method which is used to identify and analyze the ways in which system components can fail and the resulting effects on the system. This method uses a spreadsheet similar to the one shown in Figure 35.4.

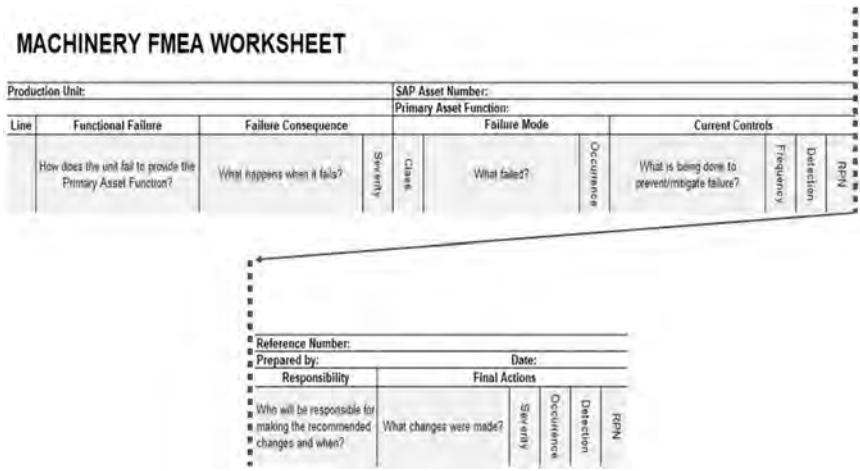


FIGURE 35.4
Example of failure modes and effects analysis (Source: Yates, W. David 2024).

Fault Tree Analysis (FTA)

The Fault Tree Analysis (FTA) begins with an undesired event and then determines all the ways it could occur. This method uses a graphical technique that identifies primary causes of accident, injury, or type of incident investigation, such as maintenance and operations issues.[6] A fault tree diagram is established as a visual framework of events preceding an event to the point of failure. It uses a series of "AND" and "OR" gates, as shown in Figure 35.5.

Event Tree Analysis (ETA)

An Event Tree Analysis (ETA) is another form of graphical representation that illustrates the mutually exclusive sequences of events that could arise from an initiating event and the resulting consequences. Each event can be quantified as shown in Figure 35.6 to provide probabilities of the different possible outcomes. One of the major differences between Event Tree Analysis (ETA) and Fault Tree Analysis (FTA) is that the ETA includes events leading to the incident.

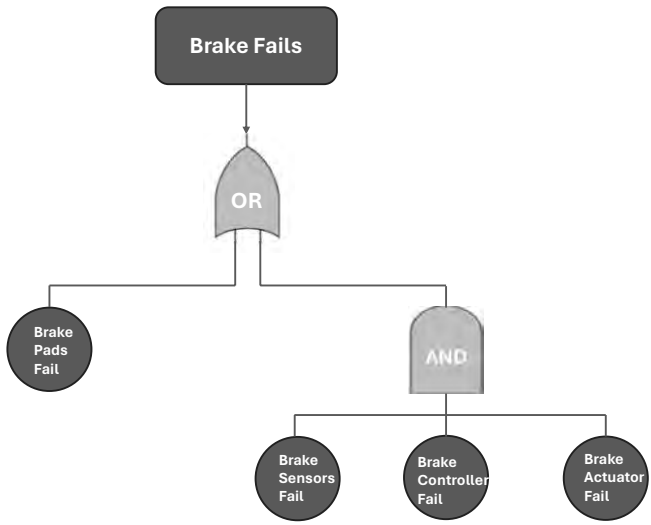


FIGURE 35.5
Fault tree analysis (FTA) example[7] (Source: Yates, W. David 2024).

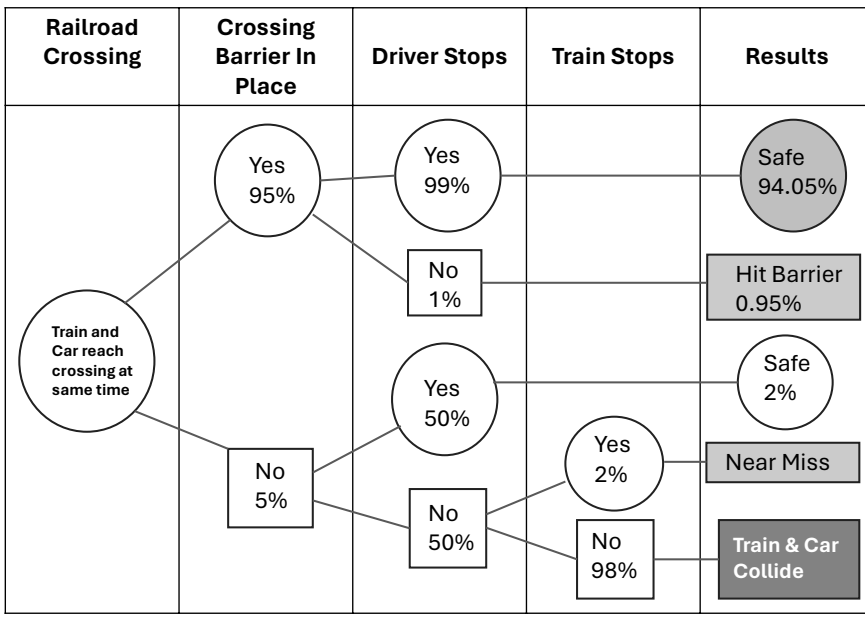


FIGURE 35.6
Example event tree analysis (Source: Yates, W. David 2024).

Design Safety Reviews

Design safety reviews are essential in anticipating and identifying potential hazards during the design or redesign processes. The primary purpose is to avoid hazards through the design of a new system or the redesign of an existing system. They are most effective when applied in the early stages of the process. The process incorporates the establishment of a design safety review team, review procedures and methods, selecting a review method, the assessment of the design, the review of any deviations, and approval process. In addition, a defined action plan to deal with review findings should also be implemented. A formalized design safety review process begins with a written policy signed off by management.

The Design Safety Reviews are:

- Used for new designs and facilities.
- Used for existing facilities in expansions.
- Used for modifying process systems.
- Used to evaluate equipment, machinery, and products.

Key Information to Remember on Prevention through Design (PtD)

1. The primary purpose of this PtD is to prevent or reduce occupational injuries, illnesses, and fatalities by including prevention considerations that impact workers in the design or redesign phase of projects.
2. Prevention through Design can be defined as the practice of addressing safety and health needs in the design and redesign process to prevent or minimize the work-related hazards and risks associated with the construction, manufacturing, use, maintenance, retrofitting, and disposal of a facility's processes, materials, and equipment.
3. An acceptable risk is the risk that has been reduced in both probability and severity to the lowest level reasonably possible for the conditions and environment in which it is being considered.
4. Risk is an estimate of the probability and severity of a hazard-related incident or exposure occurring.
5. The American National Standards Institute (ANSI Z590.3) Hierarchy of Controls Model will be used, which consists of Avoidance, Elimination, Substitution, Engineering Controls, Warnings,

Administrative Controls, and Personal Protective Equipment (PPE), which are ranked in order from most effective to least effective.

6. Preliminary Hazard Analysis (PHA) is a primary feature of system safety that is used to identify and categorize hazards or potential hazards of a specific operation.
7. What-if analysis is a team-based qualitative method that is used to identify and analyze hazards, hazard scenarios, existing controls, and needed additional controls.
8. The Hazard and Operability Study (HAZOP) is a qualitative method used to identify both hazards and operability problems.
9. Failure Modes Effect Analysis (FMEA) is a detailed qualitative or semi-qualitative method which is used to identify and analyze the ways in which system components can fail and the resulting effects on the system.
10. The Fault Tree Analysis (FTA) begins with an undesired event and then determines all the ways it could occur.
11. An Event Tree Analysis (ETA) is another form of graphical representation that illustrates the mutually exclusive sequences of events that could arise from an initiating event and the resulting consequences.

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36

Measuring Safety and Health Performance

"You can't manage what you can't measure"

—Drucker

On OSHA's website, under the Safety & Health Management Systems eTool link, the author discusses the difference between **responsibility**, **authority,** and **accountability**. Supervisors and coordinators have responsibility, authority, and, on occasion, accountability. However, the business owner, operator, or manager has overall accountability. Therefore, there must be some form of measurement to determine success or areas in need of improvement. The elements of an effective accountability system include:

- **Established standards** in the form of company policies, procedures, or rules that clearly convey standards of performance in safety and health to employees.
- **Resources** needed to meet the standards include a safe and healthful workplace, effective training, and adequate oversight of work operations.
- A **measurement system** that specifies acceptable performance.
- **The consequences,** both positive and negative.
- **Application** at all levels.

When managers and employees are held accountable for their safety and health responsibilities, they are more likely to press for solutions to safety and health problems than to present barriers. By implementing an accountability system, positive involvement in the safety and health program is created.

Examples of measured safety behavior at various levels include:

- **Top/mid-level managers**: Measurement at this level includes personal behavior, safety activities, and statistical results, such as following company safety and health rules, enforcing safety and health rules, arranging safety and health training, and worker's compensation costs.
- **Supervisors**: Measurement should include personal safety behavior and safety activities which they are able to control, such as making sure employees have safe materials and equipment, following and enforcing safety rules, and conducting safety meetings.

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- **Employees**: Measurement usually includes personal behavior, such as complying with safety and health rules and reporting injuries and hazards (http://www.osha.gov/SLTC/etools/safetyhealth/comp1_responsbility.html[1]).

With the understanding that not only good management practices, but OSHA as well, expects a viable measurement system is put into place that holds various parties responsible and accountable, the question then becomes, "How is this to be accomplished?" When measuring safety performance, there are several aspects that must be addressed. As you will learn later in this chapter, there are various types of indicators of performance, and relying on old methods and metrics is no longer sufficient to advance the safety program of an organization.

Almost to a person, any CEO, Owner, or Business Director/Manager, when asked to describe their company's performance would describe it in terms of profit percentage, return on investment, or their share of the market. The characteristic of each of these measurements is that they are generally positive in nature, reflecting achievement, rather than negative, reflecting failure. However, if you were to ask this same group to describe their safety performance, they would inevitably mention the number of injuries or the lack thereof, incident rates, etc. Some of them may mention their reduction in overall injury/illness rates. The characteristic of each of these measurements is reflective of an injury (or in some cases, the lack of something bad occurring). Safety metrics in general have been a negative or past performance measurement (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

Major Problems with Injury/Illness Health Statistics in General

In general, the problem with traditional measurements of injury/illness health statistics is as follows:

- Under reporting: An emphasis on injury and illness rates as a measure, particularly when related to reward systems, can lead to such events not being reported to "maintain" performance.
- Whether a particular event results in an injury is often a matter of chance, so it will not necessarily reflect whether or not a hazard is under control. An organization can have a low injury rate because of luck or fewer people exposed, rather than a good health and safety management program.

- Injury rates often do not reflect the potential severity of an event, but rather the consequence. For example, the same failure to adequately guard a machine could result in a cut finger or an amputation.
- People can stay off work for reasons that do not reflect the severity of the event.
- There is evidence to show there is not necessarily a relationship between "occupational" injury statistics (e.g., slips, trips, and falls) and control of major accident hazards (e.g., loss of containment of flammable or toxic material).
- A low injury rate can lead to complacency.
- A low injury rate results in fewer data points being available.
- There must have been a failure (i.e., injury or illness) in order to get a data point.
- Injury statistics reflect outcomes and not causes (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

Some of the aspects or questions that must be answered include:

1) Why measure?
2) What do I measure?
3) When to measure?
4) Who should measure?
5) How do we measure?

Each of these questions or aspects will be discussed individually.

Why Measure Performance?

If you recall, one of the Management Theories presented in Chapter 19, known as the "Deming Cycle," states that there are four basic steps, which include (1) Plan, (2) Do, (3) Check, and (4) Act. Measurement is one method of checking—to measure, if you will—the overall performance of your safety program. It is equally important to the safety and health profession as it is to financial, production, or service delivery management (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]). At the beginning of this chapter, there is a quote by Peter Drucker, which is worth reiterating and states: "You can't manage what you can't measure." Figure 36.1 illustrates where Performance Measurement fits within the overall safety and health management system:

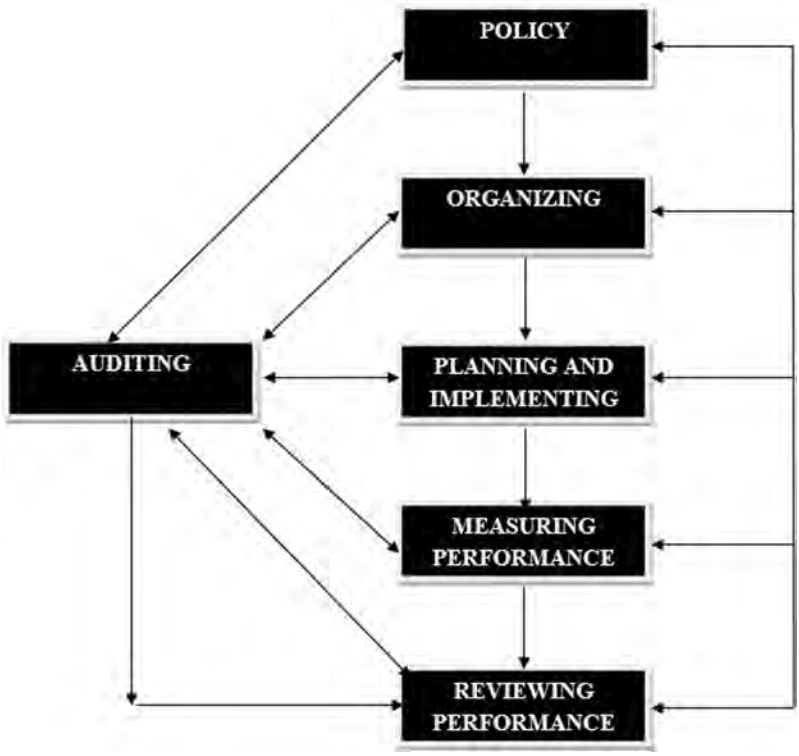


FIGURE 36.1
Health and safety performance management system (Source: Yates, W. David 2019; http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

Therefore, one of the main purposes in measuring performance is to provide information to the decision-makers and those accountable for the overall success of the program. The measurement information sustains the operation and development of the health and safety management system, and thus the control of risk, by:

- Providing information on how the system operates in practice.
- Identifying areas where remedial action is required.
- Providing a basis for continued improvement.
- Providing feedback and motivation.

As stated above, the measurement system helps in deciding:

- Where you are relative to where you want to be.
- What progress is necessary and reasonable in the circumstances?

- How that progress might be achieved against particular restraints (e.g., resources or time)?
- The way progress might be achieved.
- Priorities and effective use of resources ((http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

As has been mentioned earlier in this chapter, one of the overriding purposes of measuring health and safety performance is to hold those in charge accountable for the performance of the program(s). By measuring health and safety performance, those accountable can initially determine where they are, determine where they want to take the program, and then develop a strategic plan on how to achieve those goals and objectives. By measuring, an accountable person can continuously determine where they are relative to the goals and objectives.

What to Measure?

One thing that can be agreed upon by all safety professionals is that health and safety risks must be controlled and/or eliminated. In order to do this, they must be identified and therefore put into the system to be managed. Figure 36.2 graphically illustrates an effective risk control model:

The health and safety management system comprises three levels of control:

- **Level 1**: The key elements of the health and safety management system are the management arrangements (including plans and objectives) necessary to organize, plan, control, and monitor the design and implementation of the Risk Control System or Risk Control Management System (RCMS).



FIGURE 36.2
Effective risk control (Source: Yates, W. David 2019; http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

- **Level 2**: Risk Control Systems: the basis for ensuring that adequate workplace precautions are provided and maintained.
- **Level 3**: Effective workplace precautions are provided and maintained to prevent harm to people at the point of risk.

To effectively answer the question "What is our health and safety performance?," performance measurement should cover all elements of Figure 30.2. It should be based on a balanced approach that combines:

1) **Input**: Monitoring the scale, nature, and distribution of hazards created by the organization's activities—***measures the hazard burden***.
2) **Process**: Active monitoring of the adequacy, development, implementation, and deployment of the health and safety management system and the activities to promote a positive health and safety culture—***measures of success***, and
3) **Outcomes:** Reactive monitoring of adverse outcomes resulting in injuries, illnesses, loss, and accidents with the potential to cause injuries, illness or loss—***measures of failures***.

Measuring the Hazard Burden

An organization has many activities, and each of these activities will create hazards, which will vary in nature and significance. Therefore, the range, nature, distribution, and significance of the hazards (***the hazard burden***) will determine the risks that need to be controlled.

Most professionals can agree that the best solution is to eliminate the hazard, either by engineering it out, replacing it with another method, or simply by no longer carrying out a particular activity. However, this is not always practical or feasible, depending on the situation.

Measuring the hazard burden requires that:

- The hazard is first identified.
- The hazard is classified according to the significance of the hazard (high, moderate, or low risk).
- The hazard is categorized as to whether the significance of the hazard is consistent across the various parts of the organization.
- The hazard is determined to be consistent or variable over time.
- The hazard reduction or elimination method is successful or not.

- A determination is made on what impact business changes or processes are having on the nature and significance of the hazards (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

Measuring the Health and Safety Management System

The primary and overriding purpose of any safety and health management system is to turn uncontrolled hazards into controlled risks, and to ultimately eliminate all injuries, illnesses, and accidents. Key elements of a safety and health management system, as graphically illustrated in Figure 36.1, are:

- Policy
- Organizing
- Planning and implementation
- Measuring performance
- Audit and review

Policy

Every organization should have a written health and safety management policy. The measuring process should ensure that this written safety policy (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]):

- Exits
- Meets the legal requirements and best practices
- Is up-to-date
- Assigns specific responsibilities
- Is being implemented effectively

This last bullet point requires more discussion to ensure that it is fully understood. When conducting a self-audit, it is important to verify, through whatever means, that the policy is fully implemented. What does "fully implemented" mean? Used as a verb, Merriam-Webster Online Dictionary defines implement as follows: "CARRY OUT, ACCOMPLISH; *especially* **:** to give practical effect to and ensure of actual fulfillment by concrete measures" (http://www.merriam-webster.com/dictionary/implemented?show=0&t=1406386603[3]). Based on this definition, simply writing a health and safety policy would not be sufficient to "check the box" on the audit form. Some action must be taken to ensure that the plan is (1) communicated to all stakeholders, (2) understood by all stakeholders, and (3) put into action. The individual components of the health and safety plan can be measured or audited separately.

Organizing

Whenever you establish a measurement system, your program should be organized in such a manner to ensure that the following are present, adequate, and implemented (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]):

- That it establishes and maintains management control of health and safety in the organization.
- That it promotes effective cooperation and participation of individuals, safety representatives, and relevant groups so that health and safety is a collaborative effort.
- That it ensures the effective communication of necessary information throughout the organization.
- That it secures the competence of the organization's employees.

Planning and Implementation

When measuring the health and safety performance of an organization, it is important to assess the adequacy and implementation of the planning system, which should be able to (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]):

- Deliver plans with objectives for developing, maintaining, and improving the health and safety management system.
- Design, develop, install, and implement suitable management arrangements, risk control systems, and workplace precautions proportionate to the needs, hazards, and risks of the organization.
- Provide effective prioritization of activities based on risk assessment.
- Ensure the correct balance of resources and effort is being targeted proportionately according to the hazards/risk profile across the organization (e.g., is disproportionate effort being expended on slips/trips relative to the control of major accident hazards or fire safety?).
- Operate, maintain, and improve the system to suit changing needs and process hazards/risks; and
- Promote a positive health and safety culture.

Under the *General Duty Clause*, OSHA states that an employer shall furnish "a place of employment which is free from recognized hazards that are causing or are likely to cause death or serious physical harm to its employees." Where there is no specific standard, OSHA will use the general duty clause for the issuance of citations and fines. The general duty clause can be found in section 5 (a)(1) of the Occupational Safety and Health Act of 1970 (https://

www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=3359&p_table=oshact[4]). In complying with this requirement, it is necessary to plan and implement an effective health and safety management system.

As mentioned previously, health and safety programs should always include goals and objectives and a viable, sustainable plan to achieve them. While there are many different parts and pieces to an organization, each should be aligned with the overall organizational goals and objectives, to which the Business Manager is to be held accountable. These goals and objectives are linked to the individual components in the various departments of the organization.

It is said that a prerequisite of effective health and safety plans and objectives is that they should be SMART, which is an acronym that stands for (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]):

- **S**pecific
- **M**easurable
- **A**ttainable
- **R**ealistic/**R**elevant
- **T**imebound

Another element is measuring management arrangements and risk control systems. The measurements should address whether the program has the correct capabilities, whether the implementation of the program has been fully and correctly implemented (compliance) and whether it has been properly deployed in order to accomplish the overall goals and objectives.

Capability

In determining whether a system or plan has the capability to deliver the desired outcomes, one must ensure that the system has the necessary physical requirements and resources. Then, just as, or more important as the physical requirements and resources, are the management processes, support, and resources. Without adequate resources in terms of financial, professional resources, and management commitment, the program is doomed to failure from the very beginning.

We discussed the Plan, Do, Check, and Act (PDCA) method earlier in this chapter, but it alone is not sufficient to determine whether a program is in compliance. An example of this is if the system calls for an incident investigation and one is done. Merely doing the investigation would satisfy the requirement on a checklist but would be of no value if the incident investigation did not determine the root cause and then provide some viable recommendations for corrective or preventive actions. In other words, caution should be given that the measurement is not just "technically adequate" but is also practically adequate.

Most importantly, the plan must assign specific responsibilities. For example, some of the key positions within the systems include the following:

- President/CEO
- Department Heads
- Safety Professionals
- First Line Supervisors
- Employees

Each of these key positions has its own responsibilities and accountabilities. For example, the President/CEO may have overall responsibility for ensuring that a plan is in place, that the plan is fully funded financially, and that adequate resources are made available to accomplish the goals and objectives. The Safety Professional may be responsible for implementing the program by writing the written programs, ensuring that employees receive the appropriate training, etc.

Compliance

It is often debated whether compliance is the same as being safe. I have changed my thinking process on this a few times over the years, and currently, I fall into the category that thinks by being compliant with regulatory and corporate requirements, one lends itself to a safer and healthier workplace. Not to mention the fact that it is a requirement and, therefore, a vital aspect of any safety professional's job performance. As such, an enormous number of resources and effort is put into maintaining compliance. The trick is to make sure that compliance merges with safety.

In further discussing the health and safety plans, it is important to point out that the objectives of the program/plan can never be achieved if the individual components of the plan are not being complied with. Therefore, it is vitally important that routine checks of the progress be made to measure the status of the program and to adjust course, if need be. In a world where there are increasing demands on managers and supervisors to accomplish more with fewer resources, it is incumbent upon them to monitor the most important requirements of their jobs. As the old adage goes, "Inspect what you expect," and the likelihood that it will be accomplished is greatly increased. In doing so, it is also important to ensure that every employee fully understands how their organization is expected to operate. Many of us have been in environments where we have had two or more equally important managers to whom we report. For example, we may operationally report to a site manager or manufacturing director, while at the same time report to a

corporate health and safety director or division vice-president or president. Most times, this is not a problem; however, sometimes this gets quite tricky. Furthermore, employees must understand the actual process, such as the individual requirements/programs (energy control program, hearing conservation, etc.), as well as other issues, such as how to report a hazard, who initiates the work order, etc.

Deployment

As we've discussed, it is not enough for a plan be written and put on a shelf. It must also be implemented, which means that at some point the plan must be deployed to every employee. There are a wide variety of methods to deploy a new program or process, and each must be tailored to the individual organization. However, when doing so, the deployment process must also be measured as to the status of the deployment.

Figure 36.3 graphically illustrates the three dimensions of measurement that have been discussed above. The main goal is to be in the shaded areas of the model. Measuring all three dimensions allows management to gauge performance which they can apply at different levels. For example, looking at a specific management arrangement (e.g., competence) or risk control system (e.g., entry into confined spaces), or looking at a range of management

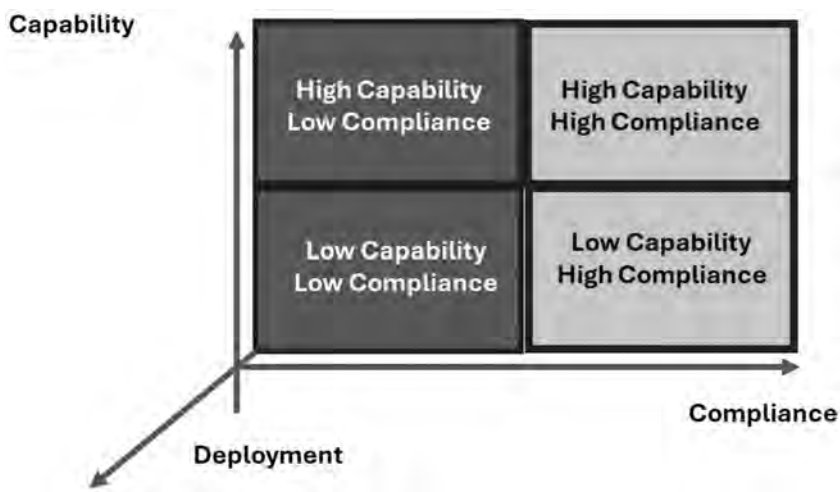


FIGURE 36.3
Three dimensions of measurement (Source: Yates, W. David 2019; http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

arrangements and risk control systems at a particular site or across the organization (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]).

When to Measure?

As you may have already seen in the preceding sections, measurement of the health and safety program is continuous in nature. If your goals and objectives follow the SMART model, then they should also allow for specific measurement intervals of the milestones. The measurements should be consistent and effective in order to allow decision-makers to determine if the overall goals and objectives will be met at the end of the final measuring period (i.e., monthly, quarterly, semi-annually, or annually). If, for example, the ending period of the current measurement is annually, then maybe monthly measuring periods are the appropriate interval by which to determine if a program is on track to achieve the overall annual goals. If the monthly measurements reveal, at any point, that the overall annual goals and objectives are not going to be met, then adjustments to the design of the system or alteration of the program may become necessary. Some key considerations when determining time intervals are as follows (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]):

- The initial design phase.
- Whenever changes are made that could impact on the operation of the systems.
- When information is obtained which indicates that the system as designed has failed in some way (e.g., when there has been an injury or significant incident);
- When data from the monitoring of the operation of the system indicate the design is flawed.
- The relative importance of the activity or precaution to the overall control of the risk.
- Where intervals for monitoring are prescribed by legislation.
- Where there is evidence of non-compliance.
- Where there is evidence of compliance.
- The relative frequency and time at which a particular activity take place.

Who Should Measure?

One of the dangers in any organization, and this happens, are all-too-often frequency, where senior management does not understand that there is a problem within their organization unless they are specifically informed. This approach is extremely dangerous and poses significant risks to organizations (http://www.hse.gov.uk/opsunit/perfmeas.pdf[2]). Therefore, it is necessary that specific systems be put into place (such as the measurement system discussed within this chapter) to indicate whether a program or plan is functional, properly operational, and ensures that corrective actions are triggered whenever deficiencies are found in the overall plan.

The question of who should measure is not as straightforward as you might think. For example, one might think that simply because we are discussing the health and safety program, the safety professional assigned would be the logical choice as the person to achieve the measurements. However, it is human nature to report only the positive aspects of any audit. As safety professionals, we understand that the value of a good audit program is to find deficiencies within our programs. However, if the program is tied to a bonus system, then the outcome of the audit may be different if that person were to audit the programs for which they were responsible. That is not to say that there would be no value in a safety professional doing their own audits. This occurs with frequent regularity and should. However, the formal audit of the program should be accomplished with both interested and disinterested parties. For example, a good audit or measurement of the system should be objective in nature, meaning that it is truly measurable without bias. Therefore, a measurement system should be verified with disinterested parties, such as an outside auditor, employee representatives, or supervisors.

How to Measure?

As we have already discussed in this chapter, the measurement criteria should be an integral part of the overall plan. For example, in your health and safety plan, you may determine that the energy control program will be audited and documented, and that a minimum of 10% of all lockout/tagout operations will be audited. Assuming that you have an energy control program that requires a permit system, you could determine how many operations had taken place on a daily or weekly basis and base the 10% on that number. In addition to auditing 10% of the lockout/tagout operations, you will get a detailed report on how the energy control program is operating. By this, I mean that when conducting audits of the energy control program in facilities that I've had experience in, a checklist approach is used that can be quantified to determine the overall compliance of the energy control program. For example, if I selected 70 lockout/tagout operations to audit and 9 of them were lacking in some issue, then my overall program would indicate that I am 87% compliant. Delving further into the system, I could determine

whether the non-compliance was related to an administrative issue, such as not signing off on the permit, or whether the deficiencies lay in the actual operational aspect of the program, such as failure to isolate a particular valve or electrical source within the system. The operational aspect of the program would be an indication of greater magnitude than that of an administrative error and therefore adjustments to the system can be made.

Oftentimes, many of the programs/plans are audited or measured on an individual basis rather than an overall one-time measurement. As mentioned in the above paragraph, for example, my preference for the energy control program is to conduct weekly audits/measurements of the operations, then roll them up into a monthly and annual audit/measurement report. The frequency and the exact method of how to measure is tailored to the individual organization. As to how to actually perform the measurements, which have already been established in the plan, I prefer the use of forms and checklists that cover the individual aspects of the program.

Leading versus Lagging Indicators

The one thing that I believe every safety professional can agree on is that the overall goal is to ultimately eliminate and, in the interim, reduce injuries to the lowest possible levels. To do this, we have all searched for the magic tool that will accomplish this goal. In systematically working our way towards this goal, safety professionals like to quantify information to, hopefully, predict our next event. Therefore, we are continually looking for the best safety metrics to monitor.

Ask any safety professional what their safety metrics are, and undoubtedly, almost all, if not everyone, will tell you that they track Total Case Incident Rates (TCIR), Severity Rates (SR), and Days Away, Restricted or Transferred (DART). These indicators are, of course, required by both MSHA and OSHA. These metrics are known as lagging indicators, meaning that the events measured have already occurred and are not necessarily predictors of future events. The financial markets have proven this time and time again. If a stock price rose 10% over a 5-year period, then that measurement is no indication of future stock prices.

As Terry L. Mathis, Founder and CEO of ProAct Safety, succinctly put it in an article entitled *"5 New Metrics to Transform Safety"* (http://proactsafety.com/uploads/file/articles/5-new-metrics-to-transform-safety.pdf[5]).

> Safety has historically been measured by its failures. We first measured simply the cost of safety failures and then began to calculate the number and severity of failures. When we realized that numbers did not account for exposure, and thus did not enable comparative metrics, we began to

> calculate the ratio or rate of our failures per exposure. OSHA selected the magic number of 200,000 hours worked as the standard fo calculating accident rates. The standards were then set to define what an accident is and determine what severity of injury constituted the necessity to report the accident.

The question then becomes how valuable to an organizational safety program are lagging indicators? The answer to this question is not an easy one. Besides being required by MSHA and OSHA, most corporate measurements mandate these to gauge how well a safety program has performed over the past year. Have we reduced or eliminated the number of injuries? Have we reduced the severity of injuries? So, in this sense, it does provide some measurements of past safety performance. However, these measurements are of little value as predictors of future incidents.

In every interview or discussion that I've had with corporate directors regarding metrics over the past 5–10 years, I've been asked what leading indicators I use and which ones are the best predictors of future incidents. I will add at this point, if you're looking for an absolute answer in this chapter, you can stop reading. There are no magic bullets, and these indicators can vary from company to company and from program to program. In this chapter, I will provide some examples of leading indicators and a discussion of each that I have found over the years.

In an article written by Fred A. Manuele in the December 2009 *Professional Safety* magazine, he states that Marlowe and Skrabak (2007) imply that the selection of leading indicators is largely judgmental and only time will tell whether the indicators selected are the right ones (Professional Safety[6]). In other words, even leading indicator information has some lagging indicator qualities, the difference being that leading indicators do provide some correlation between measured data and reduced incident rates.

What are the characteristics or traits of a good leading indicator? In a report published by the International Council on Mining and Metals (ICMM, 2012[7]) good leading indicators must be reliable, repeatable, consistent, and independent. To be of use in improving safety and health, both leading and lagging indicators should:

- Allow accurate and detailed comparisons.
- Lead to correct or help avoid erroneous conclusions.
- Be well understood by everyone, especially those responsible for implementing change.
- Have a quantitative basis (even when measuring a qualitative dimension).
- Measure what they are supposed to, consistently, accurately, and reliably.

- Collect information that is relevant to the required management decisions and actions.
- Adequately map and identify causal linkages (root causes, precursors, events, and outcomes).
- Prompt an appropriate response, leading to a consistent focus on implementing change.

Safety indicators are designed, or rather should be designed, to measure performance to identify problem areas, stimulate actions, document management efforts, and reinforce improvements in behavior. The distinguishing feature between leading and lagging indicators is that these objectives are achieved before the potential harm (leading) or after the potential harm (lagging) (ICMM, 2012[6]). Table 36.1 illustrates the key difference between the characteristics of leading and lagging indicators:

TABLE 36.1

Key Differences between the Characteristics of Leading and Lagging indicators

LEADING INDICATORS	LAGGING INDICATORS
Are actionable, predictive, and relevant to objectives	Are retrospective
Identify hazards before the fact	Identify hazards after the fact
Allow preventative actions before the hazard manifests as an incident	Require corrective actions to prevent another similar incident
Allow response to changing circumstances through implementing control measures before the incident	Indicate that circumstances have changed; control measures can be implemented after the incident
Measure effectives of control systems	Measure failures of control system
Measure inputs and conditions	Measure outcomes
Direct towards an outcome that we want or away from an outcome that we don't want	Measure the current outcome without influencing it
Give indications of systems conditions	Measure system failures
Measure what might go wrong and why	Measure what has gone wrong
Provide proactive monitoring of desired state	Provide reactive monitoring of undesired effects
Are useful for internal tracking of performance	Are useful for external benchmarking
Identify weaknesses through a risk control system	Identify weaknesses through incidents
Are challenging to identify and measure	Are easy to identify and measure
Evolve as organizational needs change	Are static

Source: ICMM (2012).[6]

Continuous Improvement

As mentioned earlier in this chapter, there are no specific indicators that work across the board for every situation, and they must be individually selected for each organization and circumstance. With that in mind, whatever indicator you choose, it must be considered a part of your continual improvement process. You may begin by measuring one aspect of your safety program in order to get to the next step.

Over the span of my 30-plus-year career, some of the metrics that I've used, some of which I currently use, and some I have discarded altogether are listed here and will be discussed individually:

- Near misses
- Number of safety observations
- Number of participants in the safety observation program
- Number of inspections/audits performed
- Number of safety-related work orders completed
- Number of corrective actions taken
- Employee perceptions of the safety culture
- Quantitative measurements of audit programs (tracking of scores)

Near Misses

The first and most common "leading indicator" that people think of is the number of near misses reported. Whether it is a leading or a lagging indicator can be debated. As Phil La Duke posted on his blog: http://philladuke.wordpress.com/2013/06/10/misleading-indicators/[8].

> Near misses in themselves aren't leading indicators; they are things that almost killed or injured someone, and most importantly, they are events that happened in the past. Not that anything that happened in the past has to be automatically counted out as a lagging indicator, but unless you still cling to the idea proffered by Heinrich that there is a strict statistical correlation between the number of near misses and fatalities, near misses are no more a leading indicator than your injury rate, lost work days or first aid cases. They simply tell you that something almost happened, and nothing more.

His statement would make you think that near miss reporting should be discounted as a leading indicator and placed in the lagging indicator category. He goes on to make the statement, to which I wholeheartedly believe in, is that near-miss reporting is indeed a leading indicator because when people report near misses they: (a) are more actively engaged in safety day-to-day and (b) the more the individual reports near misses, the better he or she is at

identifying hazards. In addition, he states that to gage the robustness of your safety process, measuring the level of participation in near miss reporting is a good leading indicator. Just to clarify, it is the participation, and not the actual number of near misses, that serves as a good leading indicator.

Number of Safety Observations

In my opinion, this metric has become a favorite among many organizations for several reasons. It makes companies feel good when they focus on the number of observations, then they increase their numbers. It is easily quantified and measured. The problem that I've experienced with this metric is that many companies either set a quota for each employee or establish a bonus system for those who submit a certain number. For example, a company may have a policy that says if you complete two safety observations per month, then you will be eligible for a $50 gift card drawing. In addition, for each month you qualify, you will receive one chance at the end of the year for the large drawing, which may be a $1000 award or an item such as a four-wheel ATV. Other problems with this approach are that the employees may be "pencil-whipping" the observations just to become eligible for the awards.

With this said, this metric is not without its value. By increasing the number of observations, there is more focus on the safety aspects of the job. In addition, by increasing the number of observations, employees are at least minimally engaged in the process.

Number of Participants in the Safety Observation Program

Measuring the number of participants over time has become one of my favorite indicators to monitor. Similar to the metrics listed above, there are some real or perceived problems, such as the fact that an employee may be participating in the program just to qualify for the bonus or award. This is a real concern. However, at least in my opinion, the real value in this measurement or metric is that for whatever reason, employees are participating in the program and their focus is on the observation process, at least in the few moments that it takes to conduct the observation. In addition, in my experience, whenever I'm doing observations, I will see discrepancies in an employee's behavior or actions and realize that I have made the same errors while performing that task.

Number of Inspections/Audits Performed

A valuable metric that I've found useful, especially with regard to measuring the performance of safety inspectors, professionals, and first-line supervisors, is that of the number of inspections or audits conducted in their assigned areas of responsibility. By increasing this number, you achieve several different objectives, as follows:

- Increase the visibility of safety personnel and first-line supervisors, demonstrating and communicating the idea that "Management Cares."
- Supervisors and safety professionals get out and know their respective areas.
- Communication is greatly increased when key leadership is involved. (Note: In the organizations that I've been involved in, weekly conversations with intent (focused messages, such as wearing of enhanced eyewear) must be held with employees during the audits and therefore conversations with intent are a sub-measurement of this metric); and
- Timely corrections of discrepancies can be made.

Quantitative Measurements of Audit Programs (Tracking of Scores)

As previously stated, I prefer the use of checklists for almost every aspect of the safety programs that I've designed, implemented, or been responsible for maintaining. As such, I've developed standardized audit/inspection forms that have quantifiable and weighted measurements for various aspects of the audit (see Chapter 29—Audit Procedures and Checklists for examples). These forms and checklists allow for consistent measurements of individual audits of facilities. One of the metrics that I am partial to is the measurement and tracking of the overall and individual scores which will, hopefully, show a continual increase in compliance. However, if the opposite holds true and there is a decline, even temporary, immediate corrective measures can be taken to improve the program or correct specific deficiencies.

Percentage of Safety-Related Work Orders Completed

Absolutely, one of my favorite metrics to monitor is the percentage of safety-related work orders completed. This is a very strong indicator of how well the maintenance portion of your safety program is functioning. With this being said, an important aspect of this measurement is that there must be a clear definition of what constitutes a safety-related work order. Someone capable of determining whether it is or is not a safety-related work order must be included in the process. Otherwise, this metric can become skewed, as many in the organization will code work orders as safety-related, simply to get it moved to a higher priority.

Employee Perceptions of the Safety Culture

This metric can be a valuable tool in evaluating the overall employee perceptions of the safety program. However, it is probably one of the most difficult to measure. The survey itself must be carefully designed with the questions carefully worded, as to remove all perceived or predetermined bias, which will give the interviewee no real options. Furthermore, it is always interesting to see the results of hourly employees compared to those of management and first-line supervisors. If this is one of the metrics that you choose to use, I would strongly suggest having the survey questions designed by a professional, then use the same questionnaire over time.

Key Points to Remember on Measuring Safety and Health Performance

1. According to OSHA, the elements of an effective accountability system include established standards, resources, a measurement system, consequences, and application.
2. Traditional measurements of safety performance, such as TCIR's, DARTs, and so on have limited or no use in predicting future incidents.
3. Major problems in using injury/illness rates include under-reporting, events being a matter-of-chance, actual injury rates not indicating the severity or potential severity, employees staying off work for reasons that do not reflect severity of the event, rates being lagging

indicators and reflecting negative attributes such as failures or the lack of something bad occurring.

4. Elements of an effective Health and Safety Performance Management System include policy, organizing, planning and implementing, measuring performance, reviewing performance, and auditing of the performance.
5. An effective measurement system is designed or should be designed to indicate where you currently are and measure periodically to where you want to be.
6. A prerequisite of effective health and safety goals and objectives should follow the acronym SMART, which represents Specific, Measurable, Attainable, Realistic/Relevant, and Time-bound.
7. Three dimensions of measurement must include compliance, deployment, and capability of the system to achieve specific and measurable goals and objectives.
8. Continuous improvement of any program must always be built into any sustainable system.
9. The value of any leading indicator must be that it engages employees and supervisors in the safety program.

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37

Safety Program Auditing Techniques and Checklist

In order to determine whether the goals and objectives of your health and safety program are on track to being met, you must measure them. Chapter 37 provides an overview as to what is expected to measure the program, whereas this chapter will help explain in more detail as to how measurements are accomplished. Examples of some useful tools will also be provided to further help the practicing safety professional.

Purpose of Auditing

The paramount objective of any health and safety audit program is to ensure the health and safety of all employees, contractors, and visitors. This is done by

- Identifying hazards
- Assessing the hazards
- Developing controls to either eliminate or mitigate the hazards
- Implementing the appropriate controls
- Supervising and evaluating the controls to determine whether they are effective or not

In addition to identifying hazards and preventing injuries or illnesses, the health and safety audit program should assist in determining whether significant progress is being made in the overall goals and objectives. Remember, one of the main purposes of measuring health and safety performance is to help an organization determine where it currently stands and then to focus the efforts on where it wants to be.

Methodology for Conducting Audits

There are a wide variety of audit techniques in assessing the effectiveness of any health and safety program, but they all boil down to three basic methods according to the Occupational Safety and Health Administration (OSHA). Each

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of these will be discussed in greater detail throughout the chapter. They are as follows (Note: A major portion of the following sections is taken from Ref. [1]):

- Document review and verification.
- Employee interviews—interviewing employees at all levels will help determine the actual knowledge, awareness, and perceptions.
- Site condition reviews—conducting the actual site visit to perform a visual audit to determine the existing or potential hazards and identifying the weaknesses in the management systems that allowed the hazards to occur or to be "uncontrolled."

Audits can vary from unlimited to limited in scope. For example, an organization-wide health and safety audit can encompass the entire health and safety program, including record keeping, the hearing conservation program, the confined space entry program, and so on. A limited scope audit may focus on just one of these programs at a time. For example, an audit may be limited to just conducting an audit of the energy control program or just limiting it to one particular area of the facility.

Depending on the scope or level of the audit, one of these audit methods may be used, whereas a more thorough or unlimited audit may require the use of one or more of these methods. For example, whenever I conduct an audit of the energy control program, I use both employee interviews and document review/verification. While this is a limited-scope audit, the nature of the audit requires that I accomplish two things:

1. To measure the effectiveness of whether the employees have knowledge of the requirements of the energy control program.
2. To verify that the procedures listed within the energy control program. or isolation procedures are actually being followed.

Documentation Software

In recent years, technology has greatly improved to the point that every safety and health professional can document an inspection or audit on their cell phones or iPads. There are several applications available for a modest fee, such as the following:

- **iAuditor** (https://safetyculture.com/iauditor/)
- **donesafe** (https://donesafe.com/inspection-software/?gclid=EAIaIQobChMI_POC7YOf5AIVy5yzCh1f5gBFEAAYAiAAEgIlJfD_BwE)

- **Industry Safe** (https://www.industrysafe.com/capterra-safety-inspection-software-lp)
- **FormsOnFire** (https://www.formsonfire.com/mobile-inspections/?capterra_tracking_key=capterra)

The above list was provided as examples. There are numerous other applications available for fees. When selecting an application, it is important to make sure that it can be modified to your specific needs. In addition, it is important that the app has the capability to prepare reports.

Employee Interviews

Interviewing employees at all levels is a very good technique for determining the quality of health and safety training. If safety and health training is effective, employees will be able to tell you about the hazards they work with and how they protect themselves and others by keeping those hazards controlled. Every employee should also be able to say precisely what he or she is expected to do as part of the program. All employees should know where to go and the route to follow in an emergency.[1]

When conducting employee interviews, the auditor must be careful in their approach, particularly if they are an outside auditor. If you're an auditor outside of the organization, then there may be some inherent distrust among the employees (i.e., not wanting to say the wrong thing to get their company in trouble). However, if approached correctly, the auditor can quickly relieve the tension between themselves and the employees.

Employee perceptions can provide other useful information. An employee's opinion of how easy it is to report a hazard and get a response will tell you a lot about how well the hazard reporting system is working. If employees indicate that the system for enforcing safety and health rules and safe work practices is inconsistent or confusing, you will know that the system needs improvement.

Interviews should not be limited to hourly employees. Much can be learned from talking with first-line supervisors. It is also helpful to query line managers about their understanding of their safety and health responsibilities.[1]

Site Conditions and Root Causes

When conducting organization-wide audits, a safety professional must conduct a visual site investigation. Conducting a visual site investigation to look at site conditions is one of the few techniques that will help reveal

existing and, equally important, potential hazards. Not only can the visual site investigation reveal physical hazards, but it can also help reveal breakdowns in the same management systems meant to prevent or control the hazards.[1] For example, while conducting the visual site visit, you see signage requiring safety glasses and hearing protection. The presence of the signage is obviously a good indication that the communication piece of the health and safety program is being adhered to. However, as you progress in your audit, you see a large percentage of employees in the area not wearing the required personal protective equipment (PPE). The fact that a large percentage of employees are not wearing the required PPE is a very strong indicator that there is a breakdown in what is really being communicated to the employees. By not enforcing the requirement, managers and supervisors are negligent in their responsibilities. One of the benefits of the audit process is to identify hazards, risks, and breakdowns within the system and to take swift action to correct them. Now that this breakdown has been identified, it can be corrected.

Another way to obtain information about safety and health program management is through root analysis of observed hazards. This approach to hazards is much like the most sophisticated accident investigation techniques, in which many contributing factors are identified and corrected or controlled.

The audit of the worksite's health and safety program will require the use of one or more of the above methods and will vary with the organization, scope of the audit, and the individual auditor. It is now necessary to discuss the individual components of a viable health and safety program, along with useful ways to assess these components.

Elements of an Effective Health and Safety Program

Before beginning to discuss the methods and techniques used to assess the effectiveness of the health and safety program, it is necessary to determine some of the most common elements of a health and safety program.[2] OSHA, in their Voluntary Protection Program, recognizes that effective management of health and safety programs

- Reduces the extent and severity of work-related injuries and illnesses
- Improves employee morale and productivity
- Reduces workers' compensation costs

A common characteristic of an effective health and safety program is that it assigns responsibility to managers, supervisors, and employees. In addition, the program or plan provides for the inspection of facilities and an

assessment of the overall program on a regular basis for the presence of hazards in order to more readily control or mitigate them. Another characteristic is that the program allows for the orientation and training of employees to eliminate or avoid hazards.

General Guidelines

An effective health and safety program includes provisions for the systematic identification, evaluation, and prevention or control of hazards. It goes beyond the specific requirements of the law to address all hazards. OSHA requires that there be a written program. However, it should be understood that it is more important to have an actual, functional health and safety program in reality and that the written program, while required, is less important than what happens in reality. Depending on the size and complexity of the worksite, written programs take on greater importance.[2]

Major Elements

The major elements of an effective health and safety program include the following:

- Management commitment
- Employee involvement
- Worksite analysis
- Hazard prevention and control
- Health and safety training

Management Commitment

Effective health and safety programs do not just happen. The age-old adage, "I'd rather be lucky than good," most definitely does not apply to the modern safety professional. For an effective health and safety program to evolve, it requires leadership and commitment from the very top of an organization. One of the most important aspects of every well-managed company is that management regards worker safety and health as a fundamental value of the organization. Ideally, this means that concern for every aspect of the health and safety of all workers throughout the facility is demonstrated. Other recommended actions for management leadership include visible management involvement; assigning and communicating responsibility, authority, and resources to responsible parties; and holding those parties accountable. In addition, management should ensure that workers are encouraged to report hazards, symptoms, injuries, and illnesses, and that there are no programs or policies that discourage this reporting.

Visible Leadership

Successful top managers use a variety of techniques that visibly involve them in the health and safety protection of their workers. Managers should look for methods that fit their style and workplace. Some methods include:

- Getting out where you can be seen, informally or through formal inspections
- Being accessible
- Being an example, by knowing and following the rules employees are expected to follow
- Being involved by participating in the workplace Safety and Health Committee[3]

This is sometimes referred to as Management by Walking Around (MBWA) or Management by Wandering Around. This term may sound strange or unduly simple. However, the concept behind it is that management should get out of their offices and get involved in what is going on within their departments. All too often, we, as managers, are asked to write a policy or procedure, so we set aside the time and "knock it out." With the ever-increasing demands on management to produce more with fewer resources, this can become difficult. However, I would propose the thought that it all becomes a matter of priority. By way of example, I will use my own experiences with various organizations. As a safety professional, you would like to be involved in every aspect of the organization, including engineering, production, operations, maintenance and distribution, and so on. Combining this with the requirement to be involved in root cause analyses and attending every meeting that you are requested to be in, the task of getting out of the office to visit production, operation, and maintenance facilities becomes impossible. Hence, to curb this, I schedule my MBWA visits into my weekly calendar, and unless it is an emergency, these times are not interrupted. Sounds simple, doesn't it? The truth of the matter is that this did not occur overnight. It took a very direct and open conversation with my supervisor to allow me to do this. When it was explained that the visibility and focus of the safety department would be greatly improved by doing this, they readily agreed. Now, that is not to say that it is still not a struggle, primarily created by my own desire to be more involved in other aspects, but the plan must be developed, and the methods must be complied with to achieve them.

Employee Involvement

Employee involvement provides the means through which workers develop and express their own commitment to safety and health, for both themselves and their fellow workers.[4] OSHA is aware that the growing recognition of

the value of employee involvement and the increasing number and variety of employee participation arrangements can raise legal concerns. It makes good sense to consult your labor relations advisor to ensure that your employee involvement program conforms to current legal requirements.

Why should employees be involved? Because it is the right and smart thing to do, and here is why:

- Rank-and-file workers are the people most in contact with potential safety and health hazards. They have a vested interest in effective protection programs.
- Group decisions have the advantage of the group's wider range of experiences.
- Employees are more likely to support and use programs in which they have input.

Employees who are encouraged to offer their ideas and whose contributions are taken seriously are more satisfied and productive on the job. What can employees do to be involved? Examples of employee participation include the following:

- Participating in joint labor-management committees and other advisory or specific purpose committees.
- Conducting site inspections.
- Analyzing routine hazards in each step of a job or process and preparing safe work practices or controls to eliminate or reduce exposure.
- Developing and revising the site safety and health rules.
- Training both current and newly hired employees.
- Providing programs and presentations at safety and health meetings.
- Conducting accident/incident investigations.
- Reporting hazards.
- Fixing hazards within your control.
- Supporting your fellow workers by providing feedback on risks and assisting them in.

Eliminating hazards

- Participating in accident/incident investigations.
- Performing a pre-use or change analysis for new equipment or processes to identify hazards upfront before use.

Worksite Analysis

What is a worksite analysis and how often should it be done? A worksite analysis means that managers and employees analyze all worksite conditions to identify and eliminate existing or potential hazards.[5] There should be a comprehensive, baseline survey, with a system in place for periodic updates.

To help in conducting a worksite analysis, you can:

- Request a free OSHA consultation visit.
- Become aware of hazards in your industry.
- Create safety teams.
- Encourage employee reporting of hazards.
- Have an adequate system for reporting hazards.
- Have trained personnel conduct inspections of the worksite and correct hazards.
- Ensure that any changes in process or new hazards are reviewed.
- Seek assistance from safety and health experts.

Worksite analysis involves a variety of worksite examinations to identify not only existing hazards but also conditions and operations in which changes might create hazards. Effective management actively analyzes the work and the worksite to anticipate and prevent harmful occurrences.

Here is a suggested plan to identify all worksite hazards:[5]

- Conduct a comprehensive baseline survey for safety and health and periodic, comprehensive update surveys.
- Change analysis of planned and new facilities, processes, materials, and equipment.
- Perform routine job hazard analyses.
- Conduct periodic and daily safety and health inspections of the workplace.

These four major actions form the basis from which good hazard prevention and control can develop.

Comprehensive Surveys

For small business, OSHA-funded, state-run consultation services can conduct a comprehensive survey at no cost. Many workers' compensation

carriers and other insurance companies offer expert services to help their clients evaluate health and safety hazards. Numerous private consultants provide a variety of health expert services. Larger companies may find the needed expertise at the company or corporate level.

For the industrial hygiene survey, at a minimum, all chemicals and hazardous materials in the plant should be inventoried, the hazard communication program should be reviewed, and air samples should be analyzed. For many industries, a survey of noise levels, a review of the respirator program, and a review of ergonomic risk factors are needed.

Change Analysis

Anytime something new is brought into the workplace, whether it is a piece of equipment, different materials, a new process, or an entirely new building, new hazards may unintentionally be introduced. Before considering a change for a worksite, it should be analyzed thoroughly beforehand. Change analysis helps in heading off a problem before it develops. You may find change analysis useful when

- Building or leasing a new facility
- Installing new equipment
- Using new materials
- Starting up new processes
- Staffing changes occur

Hazard Analysis

Hazard analysis techniques can be quite complex. While this is necessary in some cases, frequently a basic, step-by-step review of the operation is sufficient. One of the most used techniques is the Job Hazard Analysis (JHA). Jobs that were initially designed with safety in mind may now include hazards or improper operations. When done for every job, this analysis periodically puts processes back on the safety track.

Other, more sophisticated techniques are called for when there are complex risks involved. These techniques include the following: What-If Checklist, Hazard and Operability Study, Failure Mode and Effect Analysis, and Fault Tree Analysis.

Conducting JHAs does not have to be a complex operation. For example, some of the organizations that I've been involved in use a simple form to be completed for all nonroutine tasks, where there is no written safe work procedure. These forms are simply reminders for the person completing the form to review the task at hand. Figures 37.1 and 37.2[6,7] are examples of simple JHA forms that can be used.

Date: _____

Participating Employees: _____

_____

Tasks/Jobs where injuries occur, or can occur		
How people get hurt?	What causes them to get hurt?	What safe practices or PPE are needed?
Ladders tipping over	• Ladder wat not on a level surface • Ladder was on soft ground and the leg sunk in • The person reached out too far • The ladder wasn't high enough to reach up safely – the person stoodup near the top of it. • Ladder broken or damaged	• Set ladder feet on solid level surfaces • When reaching out, keep belt buckle between the side rails of the ladder • Do not stand on the op of a stepladder or on the first step down from the top • Replace or repair ladder
Lifting heavy objects	• Trying to lift too heavy objects • Bending over at the waist when lifting • Turning (twisting back while lifting)	• Use proper lifting techniques (bend knees, don't twist) • For very heavy objects, use mechanical devices or get another person to help

FIGURE 37.1
Sample small business job hazard analysis (Source: Yates, W. David, 2019).

Health and Safety Inspections

Routine site health and safety inspections are designed to catch hazards missed at other stages. This type of inspection should be done at regular intervals, generally on a weekly basis. Over the course of my career, I have found it useful to conduct an overall, comprehensive audit or assessment of each work area monthly. When addressing larger facilities, I typically break the entire plant into workable zones. For example, if there is a large facility, I may break the facility into 5–10 workable zones and then conduct a weekly audit of one of these zones. The purpose is that by the end of the quarter, I have covered the entire facility and still have time to follow up on the corrective actions identified in the weekly audits. In addition, procedures that provide a daily inspection of the work area by supervisors and employees should be established. This can be done through the following:

- Using a checklist (I prefer this method).
- Past problem identification/discussion.

Task or Step	Hazards	Controls	Personal Protective Equipment (PPE)

FIGURE 37.2
Sample JHA form (Source: From www.lni.wa.gov/Safety/Topics/AToZ/JHA/PDFs/SampleJHA).

- Reviewing standards that apply to your particular industry.
- Input from everyone involved.
- Reviewing the company's safety practices or rules.

Other important things to remember regarding health and safety inspections include the following:

- Inspections should cover every part of the worksite.
- They should be done at regular intervals.
- In-house inspectors should be trained to recognize and control hazards.
- Identified hazards should be tracked for correction.

Information from inspections/audits should be used to improve the hazard prevention and control program.[5]

Catching Hazards that Escape Controls

After hazards are recognized and controls are put in place, additional analysis tools can help ensure that the controls stay in place and other hazards don't appear. These other tools include the following:

- Employee reports of hazards.
- Accident and incident investigations.
- Injury and illness trend analysis.

Employee Reports of Hazards

Employees play a key role in discovering and controlling hazards that may develop—or that already exist—in the workplace. A reliable system for employee reporting is an important element of an effective safety and health system. The workplace must not only encourage reporting but must also value it.

It is often helpful to establish multiple ways to report hazards so that, depending on comfort level and the nature of the issue, there are several avenues to get concerns addressed. Examples include the supervisor chain of command, safety and health committee members, voicemail box, and a suggestion box.

An effective reporting system needs

- A policy that encourages employees to report safety and health concerns.
- Timely and appropriate responses to the reporting employee.
- Timely and appropriate action where valid concerns exist.
- Tracking of required hazard corrections.
- Protection of reporting employee.s from any type of reprisal or harassment.

Accident/Incident Investigations

Accident/incident investigation is another tool for uncovering hazards that were missed earlier or that slipped by the planned controls. But it's only useful when the process is positive and focuses on finding the root cause, not someone to blame!

All accidents and incidents should be investigated. "Near misses" are considered an incident because, given a slight change in time or position, injury. or damage could have occurred. Six key questions should be answered in the accident investigation and report: who, what, when, where, why, and how. Thorough interviews with everyone involved are necessary.

The primary purpose of the accident/incident investigation is to prevent future occurrences. Therefore, the results of the investigation should be used to initiate corrective action.

Trend Analysis

The final action recommended under Worksite Analysis is the analysis of injury and illness trends over time, so that patterns with common causes can be identified and prevented. Review of the OSHA injury and illness forms is the most common form of pattern analysis, but other records of hazards can also be analyzed for patterns. Examples are inspection records and employee hazard reporting records.

- Injury and Illness Records Analysis:
  - Since there must be enough information for patterns to emerge, small sites may require a review of 3–5 years of records. Larger sites may find useful trends yearly, quarterly, or monthly.
  - When analyzing injury and illness records, look for similar injuries and illnesses.. These generally indicate a lack of hazard controls. Look for where the injury or illness occurred, what type of work was being done, the time of day, or the type of equipment.
- Analysis of Other Records:
  - Repeat hazards, just like repeat injuries or illnesses, mean that controls are not working, and patterns in hazard identification records can show up over shorter periods than accidents or incidents. Upgrading a control may involve something as basic as improving communication or accountability.

Hazards found during worksite analysis should be reviewed to determine what failure in the safety and health system permitted the hazard to occur. The system failure should then be corrected to ensure that similar hazards do not reoccur.[5]

Health and Safety Training

How do we know what the hazards are? In order to know what to look for, it's important that everyone in the workplace is properly trained.[8] This includes the floor workers, supervisors, managers, contractors, and part-time and temporary workers. Other suggestions related to training include the following:

- Only properly authorized and instructed employees should be allowed to do any job.
- Make sure no one does a job that appears unsafe.
- Hold emergency preparedness drills.
- Pay particular attention when new operations are being learned so that everyone has the proper job skills and awareness of hazards.

Supervisors and managers should be trained to recognize hazards and understand their responsibilities. Does everyone in the workplace know?

- The workplace plan in case of a fire or other emergency.
- When and where PPE is required?
- The types of chemicals used in the workplace.
- What precautions when handling them?

Training can help develop the knowledge and skills needed to understand workplace hazards and safe procedures. It is most effective when integrated into a company's overall training on performance requirements and job practices.

The content of a company's training program and the methods of presentation should reflect the needs and characteristics of the workforce. Therefore, the identification of needs is an important early step in training design. Involving everyone in this process and in the subsequent teaching can be highly effective.

The five principles of teaching and learning should be followed to maximize program effectiveness. They are as follows:

- Trainees should understand the purpose of the training.
- Information should be organized to maximize effectiveness.
- People learn best when they can immediately practice and apply newly acquired knowledge and skills.
- As trainees practice, they should get feedback.

People learn in different ways, so an effective program will incorporate a variety of training methods. Some types of health and safety training needed are as follows:

- Orientation training for site workers and contractors
- JSA, SOPs, and other hazard recognition training
- Training required by OSHA standards, including the Process Safety Management standard
- Training for emergency response people
- Accident investigation training
- Training on new processes or new equipment

Who needs training? Training should target new hires, contract workers, employees who wear PPE, and workers in high-risk areas. Managers and supervisors should also be included in the training plan. Training for managers should emphasize the importance of their role in visibly supporting the safety and health program and setting a good example. Supervisors should receive training in company policies and procedures, as well as hazard detection and control, accident investigation, handling of emergencies, and how to train and reinforce training.

The long-term worker whose job changes because of new processes or materials should not be overlooked. Additionally, the entire workforce needs periodic refresher training in responding to emergencies.

Plan to evaluate the training program when initially designing the training. If the evaluation is done right, it can identify your program's strengths and weaknesses and provide a basis for future program changes.

Keeping training records will help ensure that everyone who should get training does. A simple form can document the training record for each employee. OSHA has developed voluntary training guidelines to assist in the design and implementation of effective training programs.

Assessing the Effectiveness of the Overall Health and Safety Program

Now that we have a basic understanding of what is expected or required under the OSHA standards regarding an effective health and safety program, we can now discuss some methods and techniques for assessing the individual components of the program. (Note: A major portion of the following sections is taken from Ref. [1].)

Assessing the Key Components of Leadership, Participation, and Line Accountability

Worksite Policy on Safe and Healthful Working Conditions

Documentation

One of the first areas to look at is the written health and safety program/plan/policy. If there is a written policy, does it clearly declare the priority of worker safety and health over other organizational values, such as production? Does it clearly define areas of responsibility for key players, including management, supervisors, and employees?

Interviews

When asked, can employees at all levels express the worksite policy on worker safety and health? If the policy is written, can hourly employees tell you where they have seen it? Can employees at all levels explain the priority of worker safety and health over other organizational values, as the policy intends?

Site Conditions and Root Causes of Hazards

Have injuries occurred because employees at any level did not understand the importance of safety precautions in relation to other organizational values, such as production?

Goal and Objectives for Worker Safety and Health

Documentation

If there is a written goal for the safety and health program, is it updated annually? If there are written objectives, such as an annual plan to reach that goal, are they clearly stated? If managers and supervisors have written objectives, do these documents include objectives for the safety and health program?

Interviews

Do managers and supervisors have a clear idea of their objectives for worker safety and health? Do hourly employees understand the current objectives of the safety and health program?

Site Conditions and Root Causes of Hazards (Only Helpful in a General Sense)

Visible Top Management Leadership

Documentation

Are there one or more written programs that involve top-level management in safety and health activities? For example, top management can receive and sign off on inspection reports either after each inspection or in a quarterly summary. These reports can then be posted for employees to see. Top management can provide "open door" times each week or each month for employees to come in to discuss safety and health concerns. Top management can reward the best safety suggestions each month or at other specified intervals.

Interviews

Can hourly employees describe how management officials are involved in safety and health activities? Do hourly employees perceive that managers and supervisors follow safety and health rules and work practices, such as wearing appropriate PPE?

Site Conditions and Root Causes of Hazards

When employees are found not wearing required PPE or not following safe work practices, have any of them said that managers or supervisors also did not follow these rules?[1]

Employee Participation

Documentation

Are there one or more written programs that provide for employee participation in decisions affecting their safety and health? Is there documentation of these activities, for example, employee inspection reports, minutes of joint employee-management, or employee committee meetings? Is there written documentation of any management response to employee safety and health program activities? Does the documentation indicate that employee safety and health activities are meaningful and substantive? Are there written guarantees of employee protection from harassment resulting from safety and health program involvement?

Interviews

Are employees aware of ways they can participate in decisions affecting their safety and health? Do employees appear to take pride in the achievements of the worksite safety and health program? Are employees comfortable answering questions about safety and health programs and conditions at the site? Do employees feel they have the support of management for their safety and health activities?

Site Conditions and Root Causes of Hazards (Not Applicable)

Assignment of Responsibility

Documentation

Are responsibilities written out so that they can be clearly understood?

Interviews

Do employees understand their own responsibilities and those of others?

Site Conditions and Root Causes of Hazards

Are hazards caused in part because no one was assigned the responsibility to control or prevent them? Are hazards allowed to exist in part because someone in management did not have the clear responsibility to hold a lower-level manager or supervisor accountable for carrying out assigned responsibilities?

Adequate Authority and Resources

Documentation (Only Generally Applicable)

Interviews

Do safety staff members or any other personnel with responsibilities for ensuring the safe operation of production equipment have the authority to shut down that equipment or to order maintenance or parts? Do employees talk about not being able to get safety or health improvements because of cost? Do employees mention the need for more safety or health personnel or expert consultants?

Site Conditions and Root Causes of Hazards

Do recognized hazards go uncorrected because of a lack of authority or resources? Do hazards go unrecognized because greater expertise is needed to diagnose them?

Accountability of Managers, Supervisors, and Hourly Employees

Documentation

Do performance evaluations for all line managers and supervisors include specific criteria relating to safety and health protection? Is there documented evidence of employees at all levels being held accountable for safety and health responsibilities, including safe work practices? Is accountability accomplished through either performance evaluations affecting pay and promotions or disciplinary actions?

Interviews

When you ask employees what happens to people who violate safety and health rules or safe work practices, do they indicate that rule breakers are clearly and consistently held accountable? Do hourly employees indicate that supervisors and managers genuinely care about meeting safety and health responsibilities? When asked what happens when rules are broken, do hourly employees complain that supervisors and managers do not follow rules and are never disciplined for infractions?

Site Conditions and Root Causes of Hazards

Are hazards occurring because employees, supervisors, or managers are not being held accountable for their safety and health responsibilities? Are

identified hazards not being corrected because the persons assigned the responsibility are not being held accountable?

Evaluation of Contractor Programs

Documentation

Are there written policies for onsite contractors? Are contractor rates and safety and health programs reviewed before selection? Do contracts require the contractor to follow site safety and health rules? Are there means for removing a contractor who violates the rules?

Interviews

Do employees describe hazardous conditions created by contract employees? Are employees comfortable reporting hazards created by contractors? Do contract employees feel they are covered by the same, or the same quality of, safety and health program as regular site employees?

Site Conditions and Root Causes of Hazards

Do areas where contractors are working appear to be in the same condition as areas where regular site employees are working? Better? Worse? Does the working relationship between site and contract employees appear cordial?

Assessing the Key Components of Worksite Analysis

Comprehensive Surveys, Change Analysis, and Routine Hazard Analysis

Documentation

Are there documents that provide a comprehensive analysis of all potential safety and health hazards of the worksite? Are there documents that provide both the analysis of potential safety and health hazards for each new facility, equipment, material, or process, and the means for eliminating or controlling such hazards? Does documentation exist of the step-by-step analysis of the hazards in each part of each job, so that you can clearly discern the evolution of decisions on safe work procedures?

If complicated processes exist with a potential for catastrophic impact from an accident but low probability of such an accident (as in nuclear power or chemical production), are there documents analyzing the potential hazards

in each part of the processes and the means to prevent or control them? If there are processes with a potential for catastrophic impact from an accident but low probability of an accident, have analyses such as "fault tree" or "what if?" been documented to ensure enough backup systems for worker protection in the event of multiple control failures?

Interviews

Do employees complain that new facilities, equipment, materials, or processes are hazardous? Do any employees say they have been involved in job safety analysis or process review and are satisfied with the results? Does the safety and health staff indicate ignorance of existing or potential hazards at the worksite? Does the occupational nurse, doctor, or other health care provider understand the potential occupational diseases and health effects in this worksite?

Site Conditions and Root Causes of Hazards

Have hazards appeared where no one in management realized there was potential for their development? Where workers have faithfully followed job procedures, have accidents or near misses occurred because of hidden hazards? Have hazards been discovered in the design of new facilities, equipment, materials, and processes after use has begun? Have accidents or near misses occurred when two or more failures in the hazard control system occurred at the same time, surprising everyone?

Regular Site Safety and Health Inspections

Documentation

If inspection reports are written, do they show that inspections are done on a regular basis? Do the hazards found indicate a good ability to recognize those hazards typical of this industry? Are hazards found during inspections tracked to ensure complete correction?

What is the relationship between hazards uncovered during inspections and those implicated in injuries or illnesses?

Interviews

Do employees indicate that they see inspections being conducted, and that these inspections appear thorough?

Site Conditions and Root Causes of Hazards

Are the hazards discovered during accident investigations those that should have been recognized and corrected by the regular inspection process?

Employee Reports of Hazards

Documentation

Is the system for written reports being used frequently? Are valid hazards that have been reported by employees tracked to ensure complete correction? Are the responses timely and adequate?

Interviews

Do employees know whom to contact and what to do if they see something they believe to be hazardous to themselves or coworkers? Do employees think that responses to their reports of hazards are timely and adequate? Do employees say that sometimes when they report a hazard, they hear nothing further about it? Do any employees say that they or other workers are being harassed, officially or otherwise, for reporting hazards.?

Site Conditions and Root Causes of Hazards

Are hazards ever found where employees could reasonably be expected to have previously recognized and reported them? When hazards are found, is there evidence that employees had complained repeatedly but to no avail?

Accident and Near-Miss Investigations

Documentation

Do accident investigation reports show a thorough analysis of causes, rather than a tendency to automatically to blame the injured employee? Are near misses (property damage or close calls) investigated using the same techniques as accident investigations? Are hazards that are identified as contributing to accidents or near misses tracked to correction?

Interviews

Do employees understand and accept the results of accident and near-miss investigations? Do employees mention a tendency on management's part to blame the injured employee? Do employees believe that all hazards contributing to accidents are corrected or controlled?

Site Conditions and Root Causes of Hazards

Are accidents sometimes caused at least partly by factors that might also have contributed to previous near misses that were not investigated, or accidents that were too superficially investigated?

Injury and Illness Pattern Analysis

Documentation

In addition to the required OSHA log, are careful records kept of first-aid injuries and illnesses. that might not immediately appear to be work-related? Is there any periodic, written analysis of the patterns of near misses, injuries, or illnesses over time, seeking previously unrecognized connections between them that indicate unrecognized hazards needing correction or control? Looking at the OSHA 200 log and, where applicable, first-aid logs, are there patterns of illness or injury that should have been analyzed for previously undetected hazards? If there is an occupational nurse/doctor on the worksite, or if employees suffering from ordinary illness are encouraged to see a nearby health care provider, are the lists of those visits analyzed for clusters of illness that might be work-related?

Interviews

Do employees mention illnesses or injuries that seem work-related to them but that have not been analyzed for previously undetected hazards?

Site Conditions and Root Causes of Hazards (Not generally applicable.)

Figure 37.3 is an example of a worksite analysis form that I developed for use in industrial and manufacturing facilities. It can easily be adapted to serve your individual needs. I prefer checklists that are weighted and provide an overall measurement.

Assessing the Key Components of Hazard Prevention and Control

(Note: A major portion of the following sections is taken from Ref. [1].)

Appropriate Use of Engineering Controls, Work Practices, Personal Protective Equipment, and Administrative Controls

Documentation

If there are documented comprehensive surveys, are they accompanied by a plan for systematic prevention or control of hazards found? If there is a written plan, does it show that the best method of hazard protection was chosen? Are there written safe work procedures? If respirators are used, is there a written respirator program?

Interviews

Do employees say they have been trained in and have ready access to reliable, safe work procedures? Do employees say they have difficulty accomplishing their work because of unwieldy controls meant to protect them? Do employees ever mention PPE, work procedures, or engineering controls as interfering with their ability to work safely?

Do employees who use PPE understand why they use it and how to maintain it? Do employees who use PPE indicate that the rules for PPE use are consistently and fairly enforced? Do employees indicate that safe work procedures are fairly and consistently enforced?

Site Conditions and Root Causes of Hazards

Are controls meant to protect workers putting them at risk or not providing enough protection? Are employees engaging in unsafe practices or creating unsafe conditions because rules and work practices are not fairly and consistently enforced? Are employees in areas designated for PPE wearing it properly, with no exceptions? Are hazards that could feasibly be controlled through improved design being inadequately controlled by other means?

Facility and Equipment Preventive Maintenance

Documentation

Is there a preventive maintenance schedule that provides for timely maintenance of the facilities and equipment? Is there a written or computerized record of performed maintenance that shows the schedule has been followed? Do maintenance request records show a pattern of certain facilities or equipment needing repair or breaking down before maintenance is scheduled or performed? Do any accident/incident investigations list facility or equipment breakdown as a major cause?

Interviews

Do employees mention difficulty with improperly functioning equipment or facilities in poor repair? Do maintenance employees believe that the preventive maintenance system is working well? Do employees believe that hazard controls needing maintenance are properly cared for?

Site Conditions and Root Causes of Hazards

Is poor maintenance a frequent source of hazards? Are hazard controls in good working order? Does the equipment appear to be in good working order?

Establishing a Medical Program

Documentation

Are good, clear records kept of medical testing and assistance?

Interviews

Do employees say that test results were explained to them? Do employees feel that more first-aid or CPR-trained personnel should be available? Are employees satisfied with the medical arrangements provided at the site or elsewhere? Does the occupational health care provider understand the potential hazards of the worksite, so that occupational illness symptoms can be recognized?

Site Conditions and Root Causes of Hazards

Have further injuries or worsening of injuries occurred because proper medical assistance (including trained first aid and CPR providers) was not readily available? Have occupational illnesses possibly gone undetected because no one with occupational health specialty training reviewed employee symptoms as part of the medical program?

Emergency Planning and Preparation

Documentation

Are there clearly written procedures for every likely emergency, with clear evacuation routes, assembly points, and emergency telephone numbers?

Interviews

When asked about any kind of likely emergency, can employees tell you exactly what they are supposed to do and where they are supposed to go?

Site Conditions and Root Causes of Hazards

Have hazards occurred during actual or simulated emergencies because of confusion about what to do? In larger worksites, are emergency evacuation routes clearly marked?

Are emergency telephone numbers and fire alarms in prominent, easy-to-find locations?

Assessing the Key Components of Safety and Health Training

Ensuring that All Employees Understand Hazards

(Note: A major portion of the following sections is taken from Ref. [1].)

Documentation

Does the written training program include complete training for every employee in emergency procedures and in all potential hazards to which employees may be exposed? Do training records show that every employee received the planned training? Do the written evaluations of the training indicate that the training was successful and that the employees learned what was intended?

Interviews

Can employees tell you what hazards they are exposed to, why those hazards are a threat, and how they can help protect themselves and others? If PPE is used, can employees explain why they use it and how to use and maintain it properly? Do employees feel that health and safety training is adequate?

Site Conditions and Root Causes of Hazards

Have employees been hurt or made ill by hazards of which they were completely unaware, whose dangers they did not understand, or from which they did not know how to protect themselves? Have employees or rescue workers ever been endangered by employees not knowing what to do or where to go in a given emergency situation? Are there hazards in the workplace that exist, at least in part, because one or more employees have not received adequate hazard control training? Are there any instances of employees not wearing the required PPE properly because they have not received proper training? Or because they simply don't want to, and the requirement is not enforced?

Ensuring that Supervisors Understand Their Responsibilities

Documentation

Do training records indicate that all supervisors have been trained in their responsibilities to analyze work under their supervision for unrecognized hazards, to maintain physical protections, and to reinforce employee training

through performance feedback and, where necessary, enforcement of safe work procedures and safety and health rules?

Interviews

Are supervisors aware of their responsibilities? Do employees confirm that supervisors are carrying out these duties?

Site Conditions and Root Causes

Has a supervisor's lack of understanding of safety and health responsibilities played a part in creating hazardous activities or conditions?

Ensuring that Managers Understand Their Safety and Health Responsibilities

Documentation

Do training plans for managers include training in safety and health responsibilities? Do records indicate that all line managers have received this training?

Interviews

Do employees indicate that managers know and carry out their safety and health responsibilities?

Site Conditions and Root Causes of Hazards

Has an incomplete or inaccurate understanding by management of its safety and health responsibilities played a part in the creation of hazardous activities or conditions?

Sample Checklist

Figure 37.3 is a sample of a quantitative checklist that can be used to conduct an industrial safety inspection.

Business Unit: _____ **Date:** _____

Area Coordinator: _____ **Safety Rep.:** _____

Section I: BBS Participation (5%)					
Item	**Weight**	**Raw Score**	**Weighted Score**	**Score**
Are area hourly personnel participating in the SWI program? (0-25% = 25 points; 26-50% = 50 points; 51-75% = 75 points and 75-100% = 100 points)	50%	75	37.5	
Are area salaried personnel participating in the SWI program? (0-25% = 25 points; 26-50% = 50 points; 51-75% = 75 points and 75-100% = 100 points)	50%	50	25	
	100%		62.5	
Total Section I Score				**3.125**

Section II: Personal Protective Equipment (5%)				
Item	**Weight**	**Raw Score**	**Weighted Score**	**Score**
Is PPE appropriate for this work area and/or assigned job tasks? (If yes = 100 points, If no = 0 points)	15%	0	0.00	
Is PPE functional and in good repair? (If yes = 100 points, If no = 0 points)	15%	100	15.00	
Have employees been properly trained and can they demonstrate acceptable proficiency in the care, use and limitations of PPE? If yes = 100 points, If no = 0 points)	40%	100	40.00	

FIGURE 37.3
Example of an industrial safety assessment team checklist.

Safety glasses, ear protection, and other protection available and their use enforced? (If yes = 100 points, If no = 0 points)		15%		100		15.00	
Are approved respirators provided for regular or emergency use where needed? Have employees been trained and fit-tested in their use? (If yes = 100 points, If no = 0 points)		15%		100		15.00	
		100%				85.00	
Total Section II Score							**4.25**

Section III: Housekeeping, Egress & Walking Surfaces (10%)							
Item		**Weight**		**Raw Score**		**Weighted Score**	**Score**
Work areas, storage rooms, penthouse, corridors & stairways are clear of clutter, debris, equipment & obstacles? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Evacuation plans exist to assist employees with disabilities? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Material is not allowed to be stored on top of cabinets where it could fall? (If yes = 100 points, If no = 0 points)		7%		0		0	
Are changes of direction or elevation readily identifiable? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Major exits and routes are unobstructed and marked with illuminated "EXIT" signs? (If yes = 100 points, If no = 0 points)		7%		0		0	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are floors clean and dry? Is drainage maintained and are gratins, mats or raised platforms used where wet processes are performed? (If yes = 100 points, If no = 0 points)		7%		0		0	
Are permanent isles and passageways appropriately marked? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Are floor load rating limits marked on plates and conspicuously posted? (If yes = 100 points, If no = 0 points)		7%		0		0	
Are combustible scrap and debris removed at regular intervals? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Are holes in the floor, sidewalk or other walking surface repaired properly, covered or otherwise made safe? (If yes = 100 points, If no = 0 points)		7%		0		0	
Is there safe clearance for walking in aisles where motorized or mechanical handling equipment is operating? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Is material or equipment stored in such a way that sharp projections will not interfere with the walkway? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Are steps on stairs and stairways designed or provided with a surface that renders them slip resistant? (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Are toe boards installed around the edges of permanent floor openings (where persons may pass below the openings?) (If yes = 100 points, If no = 0 points)		7%		100		6.66	
Heavy storage cabinets, bookcases and file cabinets secured from tipping? (If yes = 100 points, If no = 0 points)		7%		100		6.66	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

		100%				66.601	
Total Section III Score							**6.6601**
Section IV: Emergency & Fire Protection (10%)							
Item		**Weight**		**Raw Score**		**Weighted Score**	**Score**
Emergency lighting is provided, maintained, and periodically tested? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Employees have received emergency evacuation instructions and know where to find a copy of their Area/Building Emergency Action Plans? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Are all extinguishers fully charged and in their designated places? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Is access to extinguishers free from obstructions or blockage? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Do temporary office heaters have "tip over" cutoff switches and are UL approved? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Are items not allowed to be stored within 18 inches of sprinkler heads? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Are fire doors prevented from being propped open? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Is fire extinguishing equipment available when welding cutting, burning or grinding? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are materials, equipment, and trash cans kept out of the way of fire extinguishers or other emergency equipment? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Is emergency equipment easy to identify, well marked and easy to access? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Are calibrations and inspections up to date? Is it tested periodically? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Are personnel trained in the use and inspection of emergency equipment in their work area? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
Are emergency lights installed in stairwells and means of egress areas? (If yes = 100 points, If no = 0 points)		7.69%		100		7.69	
		100%				99.9703	
Total Section IV Score							**9.99703**

Section V: Machine and Tool Safety (10%)							
Item		**Weight**		**Raw Score**		**Weighted Score**	**Score**
Bench-top grinders have properly adjusted tool rests and tongue guards? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are all cord-connected, electrically operated tools and equipment effectively grounded, or of the approved double insulated type? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
Power tools are used with the correct shield, guard, or attachment, recommended by the manufacturer? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
Are portable fans provided with full guards or screens having openings ½ inch or less? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
Is documentation kept for hoses and equipment periodic inspections? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
Are all machines with moving parts properly guarded? (If yes = 100 points, If no = 0 points)		8.33%		0		0	
Are load capacities and operating speeds, conspicuously posted for machinery? (If yes = 100 points, If no = 0 points)		8.33%		0		0	
Is equipment and machinery securely placed and anchored to prevent moving? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
Is sufficient Clearance provided around and between machines to allow for safe operations, setup, serving, material handling and waste removal? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
Are all portable and fixed ladders inspected periodically for defects? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
Are pneumatic power tools secured to the hose or whip in a positive manner to prevent accidental disconnection? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are pneumatic and hydraulic hoses on power operated tools checked regularly for deterioration or damage? (If yes = 100 points, If no = 0 points)		8.33%		100		8.33	
		100%				83.3004	
Total Section V Score							**8.33004**

Section VI: Flammable and Hazardous Substances and Storage (10%)							
Item		**Weight**		**Raw Score**		**Weighted Score**	**Score**
Flammable wastes (e.g., oil or solvent rags) are discarded into an approved flammable waste container? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66	
Safety Data Sheets (SDS) are available for each hazardous substance in the work area in either hard copy or electronically? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66	
Flammable liquid quantities >10 gallons are stored in UL/FM-approved flammable liquid cabinets? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66	
Emergency eye washes and showers are readily accessible wherever corrosive or toxic materials are present? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are hazardous materials and flammable liquids stored in proper containers/cabinets? Are containers stored away from means or egress or exits? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Are storage spaces or rooms for hazardous materials marked? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Have personnel who handle chemicals been trained on the hazards involved? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Are bulk drums of flammable liquids grounded and bonded to containers during dispensing? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Are "NO SMOKING" signs posted where appropriate in areas where flammable or combustible materials are used or stored? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Is there a list of hazardous substances used in your workplace? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Is there a written Hazard Communication Program dealing with Safety Data Sheets (SDS), labeling, and employee training? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Is there an employee worksite orientation/training program before allowing employees to use hazardous substances? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66
Is each container for a hazardous substance labeled with product identity and a hazard warning (communication of the specific health hazards and physical hazards)? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are incompatible materials banned from being stored together? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66		
Is there a review procedure in place to ensure that banned materials are not entering the site, in accordance with F-02? (If yes = 100 points, If no = 0 points)		6.66%		100		6.66		
		100%				99.901		
Total Section VI Score								**9.9901**

Section VII: Electrical Safety (15%)								
Item		**Weight**		**Raw Score**		**Weighted Score**		**Score**
Are electrical enclosures such as switches, receptacles, and junction boxes provided with tight fitting covers or plates? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26		
Is each motor disconnecting switch or circuit breaker located within sight of the motor control device? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26		
Are employees prohibited from working alone on energized lines or equipment over 600 volts? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26		
Three feet of clear space is maintained in front of electrical panels? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26		
Are GFI provided near wet, damp, or conductive locations? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26		
Are breaker or motor control center panel doors closed and latched? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26		

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are employees who may reasonably face the risk of shock trained in electrical safety? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Are the necessary voltage, wattage or current ratings labeled on equipment? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Is the insulation on electrical wires free from fraying or cuts? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Is out of order equipment shut down, segregated and tagged until repaired? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Extension cords are not used in place of permanent wiring (not to exceed 6-feet in length)? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Extension cords are not frayed, spliced, cut, or otherwise in poor condition? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Do extension cords being used have a grounding conductor? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Circuit breakers are labeled to indicate which breaker controls which circuit? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	
Are multiple plug adaptors prohibited?		5.26%		100		5.26	
Are GFCI's installed on each temporary 15 or 20 ampere, 120 volt AC circuit at locations where construction/modifications are being performed?		5.26%		100		5.26	
Are flexible cords and cables free of splices or taps? (If yes = 100 points, If no = 0 points)		5.26%		100		5.26	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Are cords routed to avoid overloading outlets? (If yes = 100 points, If no = 0 points)		5.26%		100	5.26	
Is the use of metal ladders prohibited in areas where they could come in contact with energized parts of equipment, fixtures or circuit conductors? (If yes = 100 points, If no = 0 points)		5.26%		100	5.26	
		100%			99.9406	
						14.99109

Section VIII: Control of Hazardous Energy (15%)						
Item		**Weight**		**Raw Score**	**Weighted Score**	**Score**
Are provisions made to prevent machines from automatically starting when power is restored after a power failure or shutdown? (If yes = 100 points, If no = 0 points)		9.09%		100	9.09	
Are suspended loads or potential energy (such as compressed springs, hydraulics or jacks) controlled to prevent hazards? (If yes = 100 points, If no = 0 points)		9.09%		100	9.09	
Does the organization have a written Control of Hazardous Energy Program that meets the requirements of 29CFR 1910.146? (If yes = 100 points, If no = 0 points)		9.09%		100	9.09	
Are tagout procedures used if an energy isolating device cannot be locked out? (If yes = 100 points, If no = 0 points)		9.09%		100	9.09	
Are employees trained and do they understand the organization's lockout and tagout program? (If yes = 100 points, If no = 0 points)		9.09%		100	9.09	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

To the extent possible, are live parts deenergized, locked out and tagged out before personnel work on or near parts? (If yes = 100 points, If no = 0 points)		9.09%		100		9.09	
Are all equipment control valve handles provided with a means for locking-out? (If yes = 100 points, If no = 0 points)		9.09%		100		9.09	
Are appropriate employees provided with individually keyed personal safety locks? (If yes = 100 points, If no = 0 points)		9.09%		100		9.09	
Is it required that only the employee exposed to the hazard place or remove the safety lock? (If yes = 100 points, If no = 0 points)		9.09%		100		9.09	
In the event that equipment or lines cannot be shut down, locked-out and tagged, is a safe job procedure established and rigidly followed? (If yes = 100 points, If no = 0 points)		9.09%		100		9.09	
Is there an audit of lockout/tagout procedures completed at least annually? (If yes = 100 points, If no = 0 points) Last audit date: _____		9.09%		100		9.09	
		100%				99.9901	
							14.998515

Section IX: Compressed Gases and Compressed Air (5%)							
Item		**Weight**		**Raw Score**		**Weighted Score**	**Score**
Compressed gas cylinders are secured? (If yes = 100 points, If no = 0 points)		20.00%		100		20	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

(*Continued*)

Compressed gas cylinders not in use have valve protection covers in place? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
Incompatible gas cylinders are adequately separated (e.g., flammables separated from oxidizers)? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
Compressed air nozzles are provided with pressure reducing devices that restrict nozzle pressure to less than 30 psi? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
Do cutting torches have flash back preventors installed on the downstream side? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
		100%				100	
							5

Section VIII: Control of Hazardous Energy (15%)							
Item		**Weight**		**Raw Score**		**Weighted Score**	**Score**
Does the organization have a written Confined Spaces Safety Program that meets the requirements of 29CFR 1910.147? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
Are Permit Required confined spaces identified by signs to warn personnel prior to entry? (If yes = 100 points, If no = 0 points)		20.00%		100		20	

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

When entered, is a standby person assigned outside the space and in constant communication? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
Are appropriate atmospheric tests performed to check for oxygen deficiency, toxic substances and explosive concentrations in the confined space before entry? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
Is all portable electrical equipment used inside confined spaces either grounded and insulated, or equipped with ground fault protection? (If yes = 100 points, If no = 0 points)		20.00%		100		20	
		100%				100	
							15

Overall Assessment Score **92.34**

COMMENTS:

FIGURE 37.3 (CONTINUED)
Example of an industrial safety assessment team checklist.

Key Points to Remember on Safety Program Auditing Techniques and Checklists

1. In addition to identifying hazards and preventing illnesses and injuries, the health and safety program audit should assist in determining whether significant progress is being made in the overall goals and objectives of your health and safety program.
2. The three basic methods used to conduct health and safety program audits are document review/verification, employee interviews, and site inspections.
3. Inspection records can tell the evaluator whether serious hazards are being found or whether the same hazards are being found repeatedly. If serious hazards are not being found and accidents keep occurring, there may be a need to train inspectors to look for different hazards.
4. Employee interviews are extremely useful in determining the quality of health and safety training.

5. Site conditions and root causes are useful in identifying present and potential hazards in the workplace.
6. The major elements of an effective health and safety program include management commitments, employee involvement, worksite analysis, hazard prevention and control, and health and safety training.
7. One of the best methods used by managers and supervisors to continuously evaluate the health and safety effectiveness of their program is known as Management by Walking Around.
8. Employee involvement provides the means through which workers develop and express their own commitment to health and safety, for both themselves and their fellow employees.
9. Worksite analysis means that managers and employees alike analyze all worksite conditions to identify and eliminate existing or potential hazards.
10. One of the most commonly used techniques in conducting hazard analysis is the use of a Job Hazard Analysis form.

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Management of Change

Organizations that place safety as one of its highest values see Management of Change (MoC) as a critical process for success. MoC refers to the systematic approach to managing all modifications in a company's processes, operations, or organizational structure. The goal of any MoC system is to make sure that changes do not introduce new hazards or increase risks from existing ones to maintain a safe and efficient working environment.[1]

Management of Change includes an understanding of risk assessment, regulatory compliance and the methodologies for implementing change. In addition, it includes the processes used to evaluate potential impacts of changes, development of strategies to mitigate risks, and to ensure that safety protocols are updated and communicated effectively within an organization. As has already been mentioned, a key aspect is the fostering of strong safety culture values within organizations.

Management of Change (MoC) Concept

Management of Change (MoC) is considered an industry best practice, in addition to being a requirement for systems, which will be discussed in the next few paragraphs. These practices, regarding the safety profession, have evolved over time as a result of catastrophic events that have occurred primarily in the chemical industry. Major chemical accidents revealed that previous changes in processes created additional, unintentional hazards.

Management of Change Requirements under ISO Certifications

While Management of Change (or Change Management) provides many benefits to an organization, which will be discussed throughout this chapter, there are requirements for organizations to implement MoC into the organization. The International Organization for Standardization (ISO) has requirements for MoC in their certification requirements. Specifically, ISO 9001, ISO 14001, and ISO 45001 all require that certified organizations implement and maintain MoC systems to ensure that a culture of safety is embedded in the organization's operations.

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Occupational Safety and Health Administration (OSHA) Requirements for Management of Change

In addition to the ISO requirements, there are certain requirements listed in the Occupational Safety and Health Administration (OSHA) standards. Specifically, OSHA's Process Safety Management Standard, 29 CFR 1910.119(l), mandates that employers regulated under the Process Safety Management Standard establish and implement written procedures to manage changes (except for "replacements in kind" to process chemicals, technology, equipment, and procedures) and changes to facilities that affect a covered process).[2]

The Process Safety Management Standard requires the MoC system to address the following requirements[2]:

- Technical basis for the proposed change(s)
- Impact of change on the safety and health of employees
- Modifications to the operating procedures
- Necessary time period for the change; and
- The authorization requirements for the proposed change(s)

To illustrate the importance of an MoC program and where it could have benefited an organization, the following example is provided. A manufacturing Warehouse Manager and the EHS Manager conducted a survey of First In First Out (FIFO) and Block Storage areas due to concerns regarding inventory hazards caused by tip-overs and spills of heavy Ropak containers. Part of the corporate requirements is to distance workers from storage areas by the height of the stack plus ten (10) feet. Storage heights averaged fourteen (14) feet. Therefore, the distance between stacks and workers required twenty-four (24) feet. The distance in most areas was not available, so an alternative means of protecting workers involved nineteen (19) feet plus the installation of a four (4) foot physical barrier/rail. As an added benefit, the barrier allowed for the separation of powered industrial trucks and employees/pedestrians. Therefore, it was selected and implemented by the Warehouse Manager, EHS Manager, and the Facility Maintenance Manager.

After the purchase and installation of the guardrail, the Production Manager identified an issue where raw materials could not be delivered to the various workstations behind the guardrail by forklifts. As a result, a meeting was held with key stakeholders that required the guardrail to be modified with openings at various intervals to allow the forklifts to deliver raw materials.

Environmental Protection Agency (EPA) Risk Management Program (RMP)

Similar to OSHA's requirement for MoC, the EPA has a rule known as the "Risk Management Planning Rule." This rule is designed to manage risks to the surrounding community. This rule is required under Section 112(r) of the Clean Air Act Amendments, which requires the EPA to publish regulations and guidance for chemical accident prevention at facilities that use certain hazardous substances.[3] The EPA requires these companies to develop a Risk Management Plan (RMP) which:

- Identify the potential effects of a chemical accident.
- Identifies steps the facility is taking to prevent an accident.
- Spells out emergency response procedures should an accident occur.

This plan must be submitted to the local the EPA, fire, police, and emergency response personnel to prepare them for and respond to chemical emergencies within their community. It must also be provided to the public as a form of communication and awareness to improve accident prevention measures.

Benefits of Management of Change

Regardless of the various requirements to have an MoC program or system, there are many benefits to an organization including[4]:

- Improved communication
- Enhanced productivity
- Reduced stress
- Improved employee morale
- Enhanced creativity
- Improved decision-making

Improved Communication

A cornerstone element of any management of change program is effective communication. This communication is not just from management to employees but rather, communication in all directions and among key stakeholders. It begins with clear, transparent dissemination of information regarding the nature, purpose, and scope of changes. The example regarding the FIFO areas previously provided illustrates why this communication

is necessary. A systematic MoC program provides the framework and process by which that communication occurs. There are various forms of communication that can be considered, including:

- Training
- Discussion forums
- Company website to update employees on progress and changes

Enhanced Productivity

In addition to improving safety culture, one of the aims of MoC is to manage modifications in processes, technologies, and organizational structures to improve the overall productivity of the organization. An effective MoC program helps to identify opportunities where changes can streamline operations and eliminate inefficiencies. Furthermore, an effective MoC can help to enhance resource utilization.

Reduced Stress

When implemented correctly, an effective MoC program creates stability and efficiency, thereby reducing uncertainty. Each of these contributes to reducing stress to not only to operational systems but to employees and management. Change management provides clarity and structure to an organization.

Improved Employee Morale

An effective MoC program significantly influences the impact of employee morale through transparent communication. This communication involves the employee understanding the reasons for the change(s) and their role in them, including any transition period. When an organization provides adequate training and resources, employees are more competent and confident in adapting to new systems or processes. This also leads to employees' "buy-in" to the proposed changes and a greater readiness to embrace them, which increases the likelihood of successful changes.

Enhanced Creativity

When implemented correctly, an effective MoC program can unlock innovative and creative thinking among employees. Change within an organization can be frightening to employees, especially if there are unknown factors. When changes are communicated correctly and employees are included as part of the change, it can unleash these innovative and creative thoughts to facilitate a better transition and overall product.

Improved Decision-Making

By having a systematic approach to managing change, an organization's decision-making process is clearly defined. It ensures that before final decisions are made, key stakeholders have been included and allowed to provide concerns with proposed changes. This process further ensures that one of the key aspects of change management, "create no additional risks or hazards," is not allowed to take hold.

What Constitutes a Change That Requires MoC?

The answer to this question is not an easy one. Each organization is responsible for determining the types and levels of changes that are covered under certain processes. However, the following are provided as examples of triggers for the MoC process:

- When changes are made to technology, hardware, software, equipment, or facilities
- When processes require modifications, such as design specifications on parts
- Whenever there are changes to either grades or raw materials
- When there are changes to the organizational structure, including personnel or contractors
- When safety, health, and environmental controls or equipment have been proposed for change
- When there are any modifications to the building or structure
- Whenever there are changes to regulations or standards that affect the organization

There are two basic types of organizational changes: (1) adaptive changes and (2) transformational changes. Adaptive changes include small incremental changes to address the needs of an organization, such as process or equipment changes. Transformational changes involve major shifts such as mission realignment, strategy, structure, performance, and processes.[5]

Elements of a Management of Change (MoC) Program

The following elements are necessary to achieve a successful management of change program[6]:

- Leadership alignment
- Stakeholder engagement
- Communication
- Change impact and readiness
- Training
- Organizational design

Leadership Alignment

One of the most critical elements of any organization, and specifically for the management of change, is that the leadership of an organization must be aligned. Leadership alignment ensures that an organization operates in a unified direction. Effective leadership alignment begins with understanding that change objectives and the reasons behind them are communicated to all involved. Consistency in this messaging helps to mitigate confusion and breaks down resistance barriers within the organization. As has already been discussed, this communication facilitates improved decision-making that aligns with organizational goals and objectives.

Stakeholder Engagement

Another major critical element of the management of change process is stakeholder engagement. The first step to ensuring stakeholder engagement is to identify the key stakeholders, including employees, customers, suppliers, investors, and any other parties that may be impacted by the proposed changes. As with the other elements, transparent communication is vital to success. Keeping stakeholders informed of the goals, progress, and impacts of the change promotes engagement and commitment. Engagement by stakeholders further ensures that the changes or proposed changes have a greater probability of success. The earlier stakeholders are identified and engaged in the process, the more likely success will be. By including the stakeholders in the process, the organization shows that they are valued, and therefore, the changes or proposed changes are more likely to be successful and achievable.

Communication

Communication, as an element of MoC, has been discussed previously within this chapter but remains vital to the success of the MoC process. The first step in ensuring effective communication within an organization is to

establish a compelling narrative. Many organizations begin by developing a mission statement with clear objectives, goals, and values. Once this is done, the leadership team must align themselves behind a consistent message. Furthermore, organization leaders must ensure that open lines of communication exist within the organization.

By communicating with key stakeholders, it is important that there is a clear roadmap for success. This roadmap or plan should be addressed periodically, and stakeholders updated on the status of the changes. Part of this communication includes addressing any rumors which can "torpedo" an initiative that could have otherwise been successful.

Change Impact and Readiness

Whenever a change to the operations or the organization is proposed, an impact assessment must be completed to ensure unintentional and foreseeable consequences have been evaluated. During any change to a system or organization, there are potential barriers that will be identified. Once they are identified, a plan to address each barrier can be developed and implemented to ensure that the organization has assessed the required resources necessary to implement the change. These change considerations should include cultural readiness, commitment readiness, and the capacity readiness.[6]

Training

In general, adequate and effective training increases the success of any program. When it comes to the management of a change system, training is vital. Training not only creates value for the organization, but also for the employee. Training employees makes them more efficient by ensuring that they know how to correctly perform their work, which makes them better equipped to handle changes in the workplace and processes. Depending on the type of change to be implemented, it may become necessary to train management and customers. Training is performed in a variety of manners and may include live sessions, videos, on-the-job training, etc.

Organizational Design

As with any organization, the design is about creating positions or roles and responsibilities for the future state of the organization. It is vital that clearly defined roles and responsibilities are identified and communicated throughout the organization. This organizational structure, including these roles and responsibilities, must be reevaluated and modified periodically to ensure that they are the most efficient. It is important that the right person is assigned to each role, and unfortunately, the identification of people who no longer fit within the organization is necessary. Some roles may need to be outsourced, or some currently outsourced services may need to be brought back in-house.

Management of Change (MoC) Process

Depending on which model an organization adheres to, there are a varying number of steps to implementing changes within an organization. Regardless of the model used, they are all based on Deming's PDCA Model. The PDCA Model includes "Plan," "Do," "Check," and "Act" that is discussed in Chapter 29. The list that will be discussed in this chapter includes the following steps[7]:

- Identify proposed changes
- Prepare the organization for change
- Implement change, if safe
- Embed the changes within company culture and practices
- Execute and monitor change(s)

Identify Proposed Changes

Obviously, the first step in implementing a change or changes is to identify the proposed change. Recognizing that a change is necessary is often one of the most difficult aspects of an MoC program. Secondly, the organization must determine whether the change is one that requires approval using the MoC or not. A change under the MoC is an adjustment or alteration to a component, variable, or facility within an existing system, excluding those that already have existing clearly defined boundaries or responsibilities.[8] Examples of changes that are covered under the MoC process include:

- Change of process technology
- Change of facility
- Organizational structure change
- Procedure variances

The process of identifying changes begins by conducting a thorough assessment of operations to pinpoint areas where these changes may be needed. This process will also include methods for analyzing key performance data, risk assessments, and finally, reviewing applicable regulations. Key performance indicators, employee interviews, and customer feedback are additional sources of information that can be used to determine if a change is needed.

Prepare the Organization for Change

Throughout this chapter, the topic of communication and its importance has been discussed. Now it will be discussed in terms of preparing the

organization for identified changes. Once the changes have been identified and analyzed, a comprehensive plan must be developed. This plan should outline the scope of the change, the overall and specific objectives, proposed timelines, and the resources necessary to achieve success. Communication is critical on this path to success. Once the plan has been developed, it must be communicated to key stakeholders and may be conducted through training and development, website pages, face-to-face meetings, and other creative means not specifically mentioned here. Early engagement of employees in the proposed changes will provide valuable aspects that may not have been considered, as they offer a unique perspective on the actual performance of the work.

Implement the Change, If Safe

Before a change is implemented, a team of key stakeholders should develop a detailed action plan that provides a working framework for the proposed change. This plan should include the specific tasks, establish acceptable timelines, and provide a list of responsible parties and their roles in accomplishing those specific tasks. This plan should provide specifics on the required training that must be achieved at specific times for the change to be successful. This implementation plan must also be managed using established project management tools and techniques, such as Gantt charts and milestone tracking.

Embed the Changes within Company Culture and Practices

Whenever a change is made, there can be a high possibility that employees and managers may gradually, over time, revert back to the previous status quo. To prevent this possibility, leaders within the organization must ensure that the changes and the value of the changes are thoroughly embedded within the culture and practices. This can be achieved by developing, implementing, and enforcing policies and procedures, in addition to open and transparent communication with employees. Furthermore, monitoring of the changes, which will be discussed in the next section, is a vital aspect of the plan.

Execute and Monitor the Change(s)

As mentioned previously in this chapter, the basis of any successful business, operation, or safety program has as its foundation the PDCA Model of Continuous Improvement. As a reminder, PDCA is an acronym that represents "Plan, Do, Check, and Act." Under the previous sections, we discussed the planning and implementation stages of a change, now in this section the "Check" stage will be discussed. This is often the most overlooked stage in the process, but one that is vital to a successful outcome. Changes

should be monitored and evaluated at a frequency, which is identified in the implementation plan, that can identify when the implementation plan itself should

Key Information to Remember on Management of Change (MoC)

1. The goal of any MoC system is to make sure that changes do not introduce new hazards or increase risks from existing ones to maintain a safe and efficient working environment.
2. The International Organization for Standardization (ISO) has requirements for MoC in their certification requirements. Specifically, ISO 9001, ISO 14001, and ISO 45001 all require that certified organizations implement and maintain MoC systems to ensure that a culture of safety is embedded in the organization's operations.
3. OSHA's Process Safety Management Standard, 29 CFR 1910.119(l), mandates that employers regulated under the Process Safety Management Standard establish and implement written procedures to manage changes (except for "replacements in kind" to process chemicals, technology, equipment, and procedures) and changes to facilities that affect a covered process).
4. The EPA's Risk Management Rule is designed to manage risks to the surrounding community. This rule is required under Section 112(r) of the Clean Air Act Amendments, which requires the EPA to publish regulations and guidance for chemical accident prevention at facilities that use certain hazardous substances.
5. A cornerstone element of any management of change program is effective communication.
6. In addition to improving safety culture, one of the aims of MoC is to manage modifications in processes, technologies, and organizational structures to improve the overall productivity of the organization.
7. When implemented correctly, an effective MoC program creates stability and efficiency, thereby reducing uncertainty.
8. By having a systematic approach to managing change, an organization's decision-making process is clearly defined.
9. Each organization is responsible for determining the types and levels of changes that are covered under certain processes.
10. Regardless of the model used, they are all based on Deming's PDCA Model.

11. Before a change is implemented, a team of key stakeholders should develop a detailed action plan that provides a working framework for the proposed change.
12. To prevent the possibility of changes reverting to the previous status quo, leaders within the organization must ensure that the changes and the value of the changes are thoroughly embedded within the culture and practices.

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Emergency Management and Preparedness

As any organization can attest, emergencies will eventually occur at any place and time. As a result, these emergencies often cause workplace injuries or illnesses. For this primary reason, safety professionals should not only be familiar with emergency management and preparedness but be the primary resource for ensuring a comprehensive emergency management preparedness plan is developed and implemented within the organization. This chapter will cover the essential elements of a comprehensive emergency management and preparedness plan, steps to implement the plan and a system for monitoring and evaluating the plan.

Workplace Emergencies

At this point, the question may arise, "What exactly is a workplace emergency?" Simply put, a workplace emergency can refer to an unplanned or unforeseen event that could threaten the safety, health, or well-being of individuals and organizations. The first inclination for most is to think of natural disasters or medical issues. While these are included as emergencies, they do not consider the operation of the business or organization. Therefore, this chapter will address a more comprehensive view and include aspects of business continuity as well.

Standard emergencies that employers must prepare for may include:

- Inclement weather (hurricanes, tornadoes, earthquakes, floods, wildfires, winter weather, etc.)
- Chemical spills or accidental releases
- Disease outbreaks and pandemics
- Medical emergencies
- Workplace violence
- Bomb threats
- Other types of emergencies
- Fire and explosions (may contain radiation)

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In addition to the standard emergencies that employers must prepare for, there are other emergencies that should be considered for inclusion in the organization's planning, such as:

- Employee strikes
- Supply chain disruptions
- Utility outages, such as electric and water
- Civil disturbances
- Terrorism
- Transportation disruptions
- Other types of emergencies

Requirements for Emergency Management and Preparedness

While everyone may see the value of having an emergency management and preparedness plan, there are certain standards that require the development and implementation of these plans. Such standards include:

- ISO 14001 requires certified organizations to establish and maintain procedures for identifying and responding to emergencies that may have an impact on the environment.
- ISO 45001 requires certified organizations to establish, implement, and maintain process(es) needed to prepare for potential emergencies. In the emergency planning, the organization is required to include provisions for first aid, training, periodic testing, and communication to employees, visitors, and contractors. [1]
- ANSI/ASSP Z10 (American National Standards Institute/American Society of Safety Professionals Z10) has a requirement to establish and maintain emergency response plans to respond to emergencies.
- OSHA (Occupational Safety and Health Administration) in 29 CFR 1910.38 requires an employer to have an emergency action plan (EAP) whenever an OSHA standard requires one and outlines the requirements that must be met. This will be discussed in greater detail later in this chapter.[2] For the construction industry, the requirement is listed in 29 CFR 1926.35.
- MSHA (Mine Safety and Health Administration) establishes the Emergency Mine Evacuation Rule where mine operators are required to increase the availability of emergency breathing devices, improve emergency evacuation and drill training, and install lifelines for emergency evacuation.[3]

Each of these programs revolves around Edward Deming's PDCA (Plan-Do-Check-Act) Model of continuous improvement.

In addition to the general requirements listed above, OSHA has specific requirements for emergency planning, including those listed below:

- Means of egress, 29 CFR 1910.35-37 and 1926.34
- Fire Prevention Plans, Appendix—Means of Egress, for the construction industry, this can be found in 29 CFR 1926.150
- Process Safety Management for general industry is located in 29 CFR 1910.119, and for the construction industry, the requirements are located in 29 CFR 1926.64
- Hazardous Waste Operations and Emergency Response, 29 CFR 1910.120 (general industry) and 29 CFR 1926.65 (construction industry)

Emergency Management

Emergency management is a system that creates the framework by which operations, organizations, businesses, and communities reduce potential threats. Emergency managers look at these threats to the organization as potentially recurring events that have the following phases in common, which are shown graphically in Figure 39.1: Phases of Emergency Management:

- Prevention
- Mitigation
- Preparedness
- Response
- Recovery

Prevention

During daily conversations, both safety and environmental professionals use the word prevention. It is often used in connection with the term "proactive approach." As such, emergency management prevention can be described as a systematic, proactive approach to prevent emergencies from occurring in the first place. Prevention techniques require comprehensive risk assessments that identify potential threats and vulnerabilities of the organization and implement control measures that can prevent or mitigate them from becoming emergencies. These risk assessments should be continuously reviewed and updated. Most organizations will conduct this review on an annual basis.

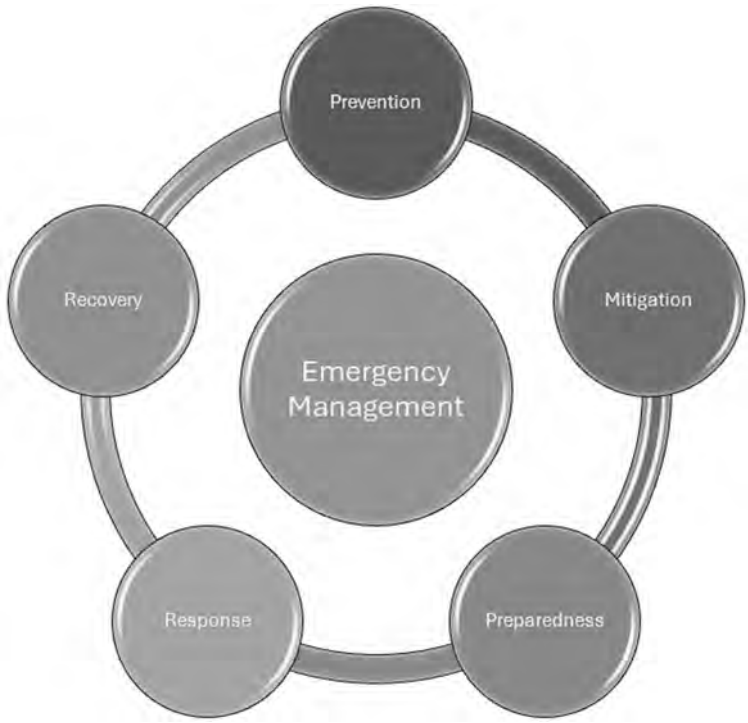


FIGURE 39.1
Phases of emergency management

Mitigation

As stated in the previous section, the goal of every safety and environmental professional is to prevent emergencies from occurring. Not all emergencies can be prevented, such as a tornado strike. However, organizations can mitigate potential risks to a level where, if these unexpected emergencies do arise, the extent of damage or harm to the organization can be greatly reduced. The purpose of mitigation is to reduce the loss of life and property through the reduction of the emergency impact.

Preparedness

Preparedness in terms of emergency management is the cycle of planning, organizing, training, equipping, exercising, evaluating, and taking corrective actions.[4] When organizations are prepared for emergencies, they are more likely to succeed in reducing the harmful impacts of emergencies on the organization, community, and employees. This phase will be discussed in greater detail later in the chapter when discussing the emergency action plan components.

Response

If a disaster or emergency occurs that causes some harm or significant impact to the organization, the next phase will be triggered, which is known as the "Response Phase." During the response, the organization is forced to react to the harmful impacts. Depending on the level of impact, this phase requires significant coordination between the organization's leadership team. As will be discussed later in the emergency action plan development, the specific roles and responsibilities must be assigned and communicated to the key stakeholders.

Recovery

Once the immediate response activities have been completed, the organization will enter the "Recovery Phase." During this phase, key functions of the organization are restored and become stabilized. The recovery phase begins after the threat to human life and facilities is no longer present. Some examples of the recovery phase include site cleanup, structural repairs to facilities (including utilities), and employee care, which may include financial assistance.

What Is an Emergency Action Plan?

Sometimes called an Emergency Response Plan, an Emergency Action Plan (EAP) refers to a pre-prepared plan that is intended to organize management and employee actions during a workplace emergency. The components of this plan will be discussed in the next section. As mentioned, OSHA, under 29 CFR 1910.38 and 29 CFR 1926.34, requires these plans to be written. The intent of such plans is to ensure employer and employee actions during emergencies do not further an otherwise chaotic environment, with the overriding purpose to prevent further injuries or property damage.

Components of an Emergency Action Plan

While OSHA has minimum requirements that an Emergency Action Plan (EAP) must include, they are minimum requirements. Prior to developing an EAP, it is important to review corporate policies, insurance carrier requirements, ISO, and other applicable sources. The Emergency Response Plan (ERP) components according to OSHA must include, at a minimum[2]:

- Procedures for reporting a fire or other emergencies.
- Procedures for emergency evacuation, including types of evacuation and exit route assignments.
- Procedures to be followed by employees who remain to operate critical plant operations before they evacuate.
- Procedures to account for all employees after evacuation.
- Procedures to be followed by employees performing rescue or medical duties
- The name or job title of every employee who may be contacted by employees needing more information about the plan or an explanation of their duties under the plan.

Reporting a Fire or Other Emergency

Considerations for reporting fires or other emergencies within a facility or organization vary greatly depending on the internal capabilities of managing emergencies. For example, if an organization has a fire department or fire brigade, the reporting procedures will be different from those organizations that rely on local fire departments. In general, however, the procedures must be written in the EAP and outline specifically how to activate the reporting system, such as dialing "911" or activating the fire alarm system by using a pull station. Regardless of the system used, it is crucial that emergency situations be reported immediately, as fires and medical emergencies can reach critical stages within seconds. Any delay in reporting may result in unnecessary loss of life or property. The procedures for activating the reporting system should be communicated to all employees through training, visual signage, drills, or other means.

Emergency Evacuation Including Type of Evacuation and Exit Route Assignments

The time to explain to employees, visitors, and contractors on the emergency evacuation procedures is not during an actual emergency. Employees, visitors, and contractors should be trained in emergency evacuation procedures during onboarding or orientation to ensure they understand when an evacuation of a facility is ordered and under what conditions it would be necessary. Each employee, visitor, or contractor must be knowledgeable about their respective evacuation and exit routes depending upon their specific location in the facility. This can be accomplished through the development of diagrams, floor plans, and through periodic emergency drills. In addition, these evacuation procedures often describe specific actions to be taken care of by employees, such as shutting windows, and doors, and shutting

off equipment. Additionally, emergency assembly areas outside the building should be included in the evacuation design plan.

Employees Who Remain to Operate Critical Plant Operations Before Evacuation

Employees who are trained to operate fire extinguishers may be assigned to remain behind during evacuation to put out small fires if they are comfortable with the task. Furthermore, certain employees may be assigned to remain behind during an evacuation to shut down special equipment if left operating, shut down chemical systems, or to shut down gas or electrical utilities to prevent further damage or harm. These duties should not unnecessarily increase the likelihood of loss of life among these employees.

Accounting of Employees After Evacuation

Accounting of employees after the evacuation is a critical step in the emergency action plan. This accountability procedure must be a written part of the EAP. If the organization is small, this can be a simple task. However, for larger organizations, it can be exceedingly difficult. How does an organization know exactly how many people are onsite at any given time? The first step is to assign employees to ensure the building has been completely evacuated by sweeping the area. Once evacuated, assigned employees (usually referred to as evacuation or fire wardens) should conduct a roll call of employees in the assembly area(s). Many employers use an electronic badge system that can be used to provide an account of those employees, visitors, and contractors onsite at any one time. Others may use a sign-in roster for employees and/or visitors. These sign-in rosters should be used to take accountability rolls. Once each assembly group is accounted for, they are called into the central incident commander. Any persons missing from the rolls must be accounted for before releasing the employee group.

Rescue and Medical Duties

The majority of companies rely on local public resources such as the fire department to provide rescue and medical services. However, not all local fire departments have the capabilities to respond to every type of emergency that may arise. For example, some areas rely on volunteer fire departments to respond. Volunteer fire departments may not be equipped or trained to respond to confined space entry rescues. Others may be trained in confined space rescue, but those trained volunteers may not show up when called, thereby delaying response times. In addition to this example, in emergencies that are widespread across the community, such as inclement weather damage or medical issues, the resources may be stretched thin. Therefore, when developing or reviewing the EAP, the organization should consult with

outside agencies to ensure that the requested services will be available and understand any limitations that may be. If these services cannot be relied upon, then modifications to the plan must be made.

Names and Job Titles of Person Who Can Be Contacted

The EAP must include the names and job titles of those people who can be contacted for training or additional information for emergencies. In addition, their specific duties and responsibilities should be included in the plan.

Emergency Planning Considerations

Hurricanes

Hurricanes can cause widespread devastation during and after they occur. The good news regarding hurricanes is that there is typically some time (a few days) to prepare for impact based on meteorological reports. The bad news is that they are powerful and can cause major destruction. Hurricanes form over ocean water and move inward over land.[5] It is important to understand the differences in emergency notifications. There are three notifications that may be issued by the National Weather Service and include:

- *Advisory*—This notification applies to tropical storm or hurricane advisories and is issued when conditions causing significant inconveniences that may be hazardous are expected. If the word "caution" is used in conjunction, then resulting conditions are not expected to be life-threatening.
- *Watch*—This notification also applies to tropical storms and hurricanes. The National Weather Service issues this notification when either the tropical storm or hurricane is expected to hit landfall within 48 h.
- *Warning*—The National Weather Service issues a "Warning" when it expects a tropical storm or hurricane within 36 h. During this warning, preparations should be completed and immediate evacuations of threatened areas should be undertaken if directed to do so by local officials.

Emergency preparations include:

- Knowing and communicating the evacuation routes.
- Knowing and communicating the location of emergency shelters.

- Establishing transportation methods, including fuel sources (filling up gas tanks for vehicles ahead of time).
- Plan for alternate communication sources. Remember, during tropical storms and hurricanes, cell phones and landlines may be inoperable. Therefore, backup radios may be necessary.
- Prepare emergency supplies, such as fuel, food, and water sources.
- Take actions necessary to protect property from wind and water damage.
- During recovery operations, generators may be necessary.
- Prepare for recovery operations, including cleanup supplies.

Tornadoes

Unlike hurricanes, tornadoes occur almost spontaneously and without warning. Tornadoes are violent, cyclonic columns of air. They can occur anytime and anywhere and may result in wind forces in excess of 200 miles per hour (mph). The path of destruction is erratic with no straight path. Tornadoes have the potential to destroy solid structures and result in the deaths of people. Tornadoes are ranked using a classification known as the "Enhanced F-Scale" or "EF". The classifications vary based on wind speed and are listed below:

- EF 0: 65–85 mph
- EF 1: 86–110 mph
- EF 2: 111–135 mph
- EF 3: 136–165 mph
- EF 4: 166–200 mph
- EF 5: >200 mph

There are two types of weather alerts that may be issued, which include Tornado Watch and Tornado Warning. Tornado watches are issued when conditions exist where tornadoes may strike and advise citizens to be prepared to take shelter immediately. A tornado warning is issued whenever a tornado has been sighted in an area and is issued to warn residents of that area to take immediate shelter.

To prepare for tornadoes, individuals and organizations should take the following precautionary actions and include them in the EAP:

- Know the county they are in and stay abreast of weather forecasts when weather conditions are likely to produce tornadoes.

- Know the community and company warning system. (Organizations should have a warning system that is different from fire alarm systems)
- Identify safe areas within the facility that will protect employees. These areas need to be marked as inclement weather or tornado shelters on facility drawings with visual signage to identify them as such. Examples of safe areas may include interior employee restrooms, designed storm shelters, or pits designed for human occupancy.
- When conditions are present that have the potential to form tornadoes, all loose materials on the outside of buildings should be brought inside or secured. Examples include chairs, hanging plants, and trash cans.

Even after a tornado has struck and passed, it is necessary to maintain continuous monitoring of television and radio alerts, as there can be more tornadoes that follow.

Chemical Spills and Releases

Chemical spills can be either simple or complex. If handled properly, the impact of a spill can be kept to a minimum. However, if handled incorrectly, chemical spills and releases can quickly escalate quickly to having devastating health impacts on employees and citizens of a community, damage to a company's brand, damage to community natural resources, and long-term effects on the ecosystem. The key to preparing for spills and releases is to conduct an inventory of those chemicals that pose a threat, knowing the adverse health effects of those chemicals, preparing pre-determined written responses in a plan, and conducting training for cleanup personnel.

It is crucial that response personnel be trained in the specific hazards of each chemical to know whether they are flammable, reactive (air or water), corrosive, or highly toxic. Response personnel must receive periodic training on spill response procedures, as well as the appropriate personal protective equipment, along with the use and limitations of spill response equipment.

Disease Outbreaks and Pandemics

Infectious diseases are caused by biological agents and organisms, such as viruses and bacteria. Oftentimes, even in localized epidemics, health care facilities are left with inadequate resources, including supplies, staff, and facilities. Most everyone can remember the effects of Covid-19 and the chaotic responses that resulted. Terms that should be understood include[6]:

- *Epidemic*: The occurrence of more cases of disease than predicted in a given area by epidemiologists or among specific groups of people over a particular period of time.
- *Outbreak*: The localized occurrence of more cases of disease as opposed to a generalized epidemic.
- *Pandemic*: Occurs over a very wide area, such as several countries or continents, usually affecting large populations.

Most organizations, along with most governments, were caught unprepared to handle a worldwide pandemic. The public watched the chaotic responses play out daily on television screens. Government responses seemed to change daily, and public communication was filled with misinformation from both public and government entities. After daily publishing new disease cases and death rates which included misinformation of its own from governments, along with being forced to take an untested vaccine that many thought was rushed and unsafe, the public felt significant mistrust of any communication, including those from government agencies such as the Centers for Disease Control (CDC). With that being said, this is what happens to any organization when they are not prepared for a specific type of emergency. Therefore, organizations and community leadership should coordinate early in the process. Companies may stockpile (before the emergency) a minimum number of personal protective equipment such as respirators, disposable gloves, and sanitizing equipment and supplies.

Medical Emergencies

Medical emergencies can be extremely traumatic and result in emotionally charged reactions. By being well-prepared to respond to medical emergencies, these stresses can be significantly reduced. The first step in preparing for medical emergencies is to take an inventory of all operations within an organization to determine the most likely scenarios of potential injury or illness types. As stated previously in this chapter, most organizations rely on the local fire departments as their medical responders. However, there are certain medical responses that should be handled by the organization itself. For example, if there are electricians on staff with the maintenance department, OSHA requires that someone on each shift be trained and certified in First Aid and CPR. It is also advisable for the organization to keep a well-stocked first aid kit or room within the facility, along with trained personnel. Automated electronic defibrillators (AEDs) should be purchased, installed, inspected, and properly maintained to respond to cardiac arrest victims. These AEDs should be located in common areas with visual signage to indicate their location, as well as be indicated on the facility floor plans.

Workplace Violence

Workplace violence is becoming more and more common in the workplace today. Workplace violence can be defined as any act or threat of physical harassment, intimidation, or other threatening disruptive behavior in the workplace. According to the National Institute of Occupational Safety and Health (NIOSH), risk factors for workplace violence can include:

- Contact with the public
- Handling money or valuables
- Delivery of passengers or goods
- Mobile workplaces (taxicab, pizza delivery, police, etc.)
- Working with emotionally and mentally unstable persons (health-care, social work, justice system, etc.)
- Working alone or in small numbers
- Working late at night
- Working in high crime areas
- Guarding valuable property or possessions
- Working in community-based settings

There are four basic types of workplace violence, which include:

a) Criminal intent—violent acts by people who enter the workplace to commit robbery or other crimes and involves people not normally associated with the organization.
b) Worker vs. customer—there is some type of relationship with employees regarding their work.
c) Current or former employee (Co-worker vs. Coworker)—there is a direct relationship between the perpetrator and the victim.
d) Non-Employee vs. Employee—personal violence conducted by someone who has no relationship with the business but has a personal relationship with an employee, such as domestic violence brought into the workplace.

Workplace violence prevention programs should include:

- Risk assessments
- Prevention and control

1. Engineering controls
2. Administrative controls

- Training and education
- Post-incident counseling
- Record keeping

Engineering controls can include improved lighting, alarm systems, communications, surveillance systems, physical barriers, and controlled entry points. Administrative controls may include increasing staff, not working alone, increasing security or security patrols, reducing early/late working hours, limiting access, and employee awareness.

Training and education must include safety and security procedures, proper conduct, and reporting procedures. In addition, workplace violence training should include identifying hazardous situations, relevant policies, security equipment, methods for diffusing threatening situations such as conflict resolution, and summoning help.

Post-Incident Counseling is provided depending on the severity of the incident. If necessary, Post-Incident Counseling should be made available to victims of workplace violence. It may be necessary, depending on the severity, to bring in a group of counselors for large-scale events or as simple as referring single employees to a counselor provided in the Employee Assistance Program (also EAP).

Record keeping is a legal requirement for an organization, no matter how minor. The Emergency Action Plan should specify to whom workplace violence incidents are to be reported, who conducts the investigations, and how they are to be documented to ensure the reporting employee's privacy.

Prevention and control measures may include pre-employment screening for the following red flags:

- Drug and alcohol abuse
- Past conflicts (especially those involving violence)
- Past violent convictions
- Defensive or hostile attitude (tendency to blame others for problems)

Bomb Threats

Bomb threats can be defined as any threat alleging pending harm or destruction from an explosive device that is received via telephone, mail, email, or other instrument of commerce.[7] There are three reasonable explanations for someone communicating a bomb threat and include:

1. The caller may have actual knowledge or belief that an explosive device is or will be placed on the property and wants to minimize any damage.

2. The caller wants to create a chaotic atmosphere, such as anxiety and panic, which will further disrupt normal activities.
3. The caller wants to discredit the leadership of the organization by creating a lack of confidence through the interjection of panic.

Regardless of the reason, every call should be taken seriously. To prepare for such communications, the organization should have clearly defined procedures for managing them. These procedures must be communicated to all employees, as anyone can receive the communication at any time. These procedures should include the following information in some form:

- If the communication (bomb threat) is received via mail, the actual paper should be handled as little as possible. This preserves key evidentiary materials, such as fingerprints, ink and font type, etc.
- If the communication is by telephone, DO NOT HANG UP. Remain calm. The intent is to get the caller to talk. Take detailed notes, listen intently to the caller, and identify background noises, such as planes or trains, etc., along with any accent or familiar geographical terms used by the caller.
- If there is a caller ID, make a note of it.
- If there is someone near (when a call is received), have them contact 9-1-1 to provide basic information and await instructions from a different phone.
- Some questions to ask the caller include:

1. Where is the bomb located? (building, floor, or room)
2. When is it expected to go off?
3. What does it look like?
4. What kind of bomb is it?
5. Did you or someone else place the bomb?
6. Why did you or someone else place the bomb?
7. What is your name?

While the call receiver is on the phone, the evacuation system should be activated by the authorized person identified in the EAP. If the call receiver is the only one available, this should be done immediately after 9-1–1 is contacted.

An actual bomb threat can be extremely stressful to the call receiver. It cannot be overstated that they must always remain calm. If an actual bomb is located, follow the EAP procedures. The procedures should include instructions to:

- NEVER touch the package or bomb or make any attempt to remove it.
- Notify the police immediately and follow their instructions.
- DO NOT activate the alarm system to evacuate the building. Communication should be done in person.
- Turn all equipment to the safe shutdown mode.
- Building occupants should assemble at designated assembly points, which are away from the building and not in front of windows or other potentially hazardous areas.
- Do not block walkways or roadways to the facility, which may prevent emergency response officials.

Fire Prevention Plan Requirements

Under 29 CFR 1910.39, OSHA requires that a fire prevention plan be written, maintained in the workplace, and made available to employees for review. At a minimum, the fire prevention plan must include[8]:

- An inventory of major fire hazards, proper handling and storage procedures for hazardous materials, potential ignition sources and their control, and the type of fire protection equipment necessary to control each major hazard.
- Procedures to control the accumulation of flammable and combustible waste materials.
- Procedures for regular maintenance of safeguards installed on heat-producing equipment to prevent the accidental ignition of combustible materials.
- Name or job title of the employee responsible for maintaining equipment to prevent or control sources of ignition of fires.
- Name or job title of the employee responsible for the control of fuel source hazards.

Note: An employer must inform employees upon initial assignment to a job of the fire hazards to which they are exposed. An employer must also review with each employee those parts of the fire prevention plan necessary for self-protection.[8]

Business Continuity Planning

The previous section of this chapter dealt with emergencies that are normally identified as posing a threat to humans or property. What happens when a business is faced with employee strikes, supply chain disruptions, long-term utility outages, civil disturbances, acts of terrorism, or transportation disruptions? Depending on the location of the organization, each of these emergencies is a likely scenarios that should be planned for. Business Continuity Plans must be developed and implemented by organizations, no matter the size, to ensure they have consistent operations and continue to deliver their products or services at their pre-defined levels and to protect the brand name of the company[9], along with safeguarding the reputations and interests of stakeholders when these events occur. Like Emergency Action Plans, Business Continuity Plans begin by identifying potential threats to the organization and then developing steps to respond to them. The key to maintaining business operations includes establishing and maintaining:

- Crisis Management Plans
- Disaster Recovery Plans
- Emergency Action and Response Plans

Crisis Management

Crisis Management is the ability of an organization to manage incidents that have the potential to cause significant security, financial, strategic, or reputational impacts. Covid-19, as has already been mentioned, created a business crisis that most businesses were unprepared to handle. This and governmental actions had severe negative impacts on both businesses and employees. Going forward, the experience has led these organizations to begin to include incidents of this nature in the Crisis Management Plan. Crisis management is not the same as risk management. Risk management involves planning for events that may occur, whereas crisis management involves responding to negative events while they occur and afterwards. The Crisis Management Plan:

- Should be a part of the overall Business Continuity Plan
- Used for managing before, during, and after an incident
- May be used for incidents that do not disrupt operations, but otherwise cause risk to the organization
- May also be activated to prevent an incident from arising.

The elements of crisis management are graphically represented in Figure 39.2.

This figure illustrates that the five P's are not sequential, but are integral to each other at all times.

Predict—During this stage, the crisis management team will identify and assess all foreseeable threats to the business.

Prevent and prepare—This stage involves putting into place any preventive measures that may mitigate the impact of threats. For example, a mining operation process involves the use of large quantities of hydrochloric acid. The company has a contract with a sole supplier to supply 100,000 gallons per week. The supplier is based in an area that is frequently impacted by hurricanes, which may disrupt their ability to supply their customers with the required amounts. The company has identified this as a potential threat and, as part of their preventive measures, has contacted other suppliers that are not in a high-risk area to supply their needs in the event the initial supplier

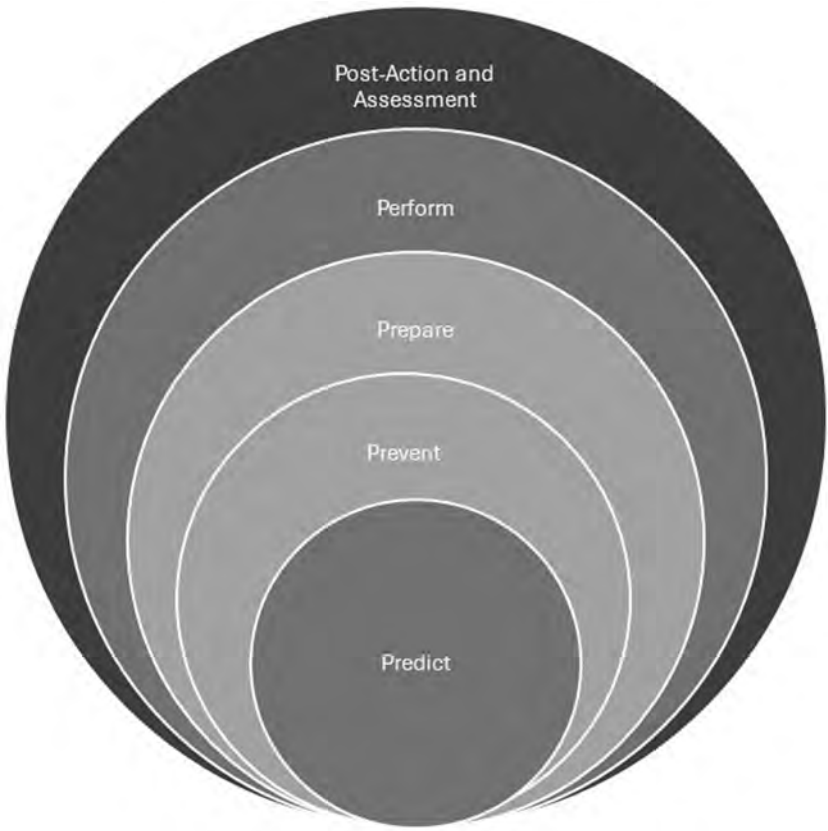


FIGURE 39.2
Five P's of crisis management.[10]

cannot meet their needs. The concern for the company is that other customers of the original supplier may also need emergency supplies if the event occurs. Therefore, the company, in their agreement with the backup supplier, agrees to purchase a minimum order per year. As an existing customer, they will be given a higher priority over non-customers if the event occurs.

Perform—This stage involves the actual implementation of planned responses and varies depending on the type of crisis being managed. It can be described as damage containment. An example to illustrate this stage involves roof damage to a facility resulting from a tornado. To prevent further damage, the facility may be required to place tarps over the roof to prevent additional damage resulting from water intrusion until the roof can be repaired. These actions should be covered in the "Disaster Recovery Plan," which is part of the overall Business Continuity Plan.

Post action and assessment—This stage may also be called the recovery stage. This stage may involve such activities as clean-up and re-establishing normal operations. The goal of this stage is to recover time, resources, and revenue. It is during this phase that a lessons-learned review should be conducted to determine what went right and what went wrong.

Business Continuity Management System

The business continuity management system includes developing a written policy or plan that defines the roles and responsibilities of employees and the management processes, which includes:

- Planning
- Implementation and operations
- Performance assessment
- Management review and improvement
- Documentation providing auditable evidence

Business continuity planning includes (a) developing and implementing risk treatment plans, (b) monitoring and reviewing plan implementation, (c) recording and reporting findings, and communicating with key stakeholders. It also involves defining critical business functions and threats, preventing threats, and developing and implementing plans. The ultimate goal is to continue operating in the event of a threat. The planning should not be conducted by an individual, but by a cross-functional team which determines the acceptable operational levels, risks the organization is willing to accept, defining the scope of work and the risk assessment of the potential threats. Finally, a good plan must be routinely and periodically reviewed to make sure it is kept current.

Business Continuity Plan Components

Components of the Business Continuity Plan should include, at a minimum, the following elements:

- Disaster recovery plan
- Information technology and infrastructure systems
- Backup systems and redundancies
- Crisis management Plan
- Emergency Action Plan

Key Information to Remember on Emergency Preparedness and Response

1. Simply put, a workplace emergency can refer to an unplanned or unforeseen event that could threaten the safety, health, or well-being of individuals and organizations.
2. Emergency management is a system that creates the framework by which operations, organizations, businesses, and communities reduce potential threats.
3. Emergency management systems include prevention, mitigation, preparedness, response, and recovery.
4. Sometimes called an Emergency Response Plan, an Emergency Action Plan (EAP) refers to a pre-prepared plan that is intended to organize management and employee actions during a workplace emergency.
5. There are two types of weather alerts that may be issued, which include Tornado Watch and Tornado Warning. Tornado watches are issued when conditions exist where tornadoes may strike and advise citizens to be prepared to take shelter immediately. A tornado warning is issued whenever a tornado has been sighted in an area and is issued to warn residents of that area to take immediate shelter.
6. Workplace violence can be defined as any act or threat of physical harassment, intimidation, or other threatening disruptive behavior in the workplace.
7. If the communication is by telephone, DO NOT HANG UP. Remain calm. The intent is to get the caller to talk. Take detailed notes, listen intently to the caller, and identify background noises, such as planes or trains, and so on, along with any accent or familiar geographical terms used by the caller.
8. Under 29 CFR 1910.39, OSHA requires that a fire prevention plan be written, maintained in the workplace, and made available to employees for review.

9. Like Emergency Action Plans, Business Continuity Plans begin by identifying potential threats to the organization and then developing steps to respond to them.
10. Crisis Management is the ability of an organization to manage incidents that have the potential to cause significant security, financial, strategic, or reputational impacts.

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BCSP Code of Ethics

Professional ethics are essential for any professional organization and profession. They are a set of codes that establish operating guidelines for any profession, which the members agree to abide by. These codes serve as overriding principles that provide professional organizations and their members with moral principles when serving the public. The Board of Certified Safety Professionals (BCSP) has an established Code of Ethics that every certificate holder must abide by. This code is republished in this Chapter and is testable information on both the Associate Safety Professional and Certified Safety Professional examinations.[1]

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BCSP Code of Ethics

This code sets forth the code of ethics and professional standards to be observed by anyone holding status with Board of Certified Safety Professionals (applicant, candidate, or credential holder). Those holding status with the Board of Certified Safety Professionals shall, in their professional activities, sustain and advance the integrity, honor, and prestige of the profession by adherence to these standards:

Standards

1. **HOLD** paramount the safety and health of people, the protection of the environment and protection of property in the performance of professional duties, and exercise their obligation to advise employers,

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clients, employees, the public, and appropriate authorities of danger and unacceptable risks to people, the environment, or property.

2. **BE** honest, fair, and impartial; act with responsibility and integrity. Adhere to high standards of ethical conduct with balanced care for the interests of the public, employers, clients, employees, colleagues, and the profession. Avoid all conduct or practice that is likely to discredit the profession or deceive the public.
3. **ISSUE** public statements only in an objective and truthful manner and only when founded upon knowledge of the facts and competence in the subject matter.
4. **UNDERTAKE** assignments only when qualified by education or experience in the specific technical fields involved. Accept responsibility for their continued professional development by acquiring and maintaining competence through continuing education, experience, professional training, and keeping current on relevant legal issues.
5. **REPRESENT** academic and professional qualifications accurately. Represent degree of responsibility in or for the subject matter in prior assignments accurately. Represent pertinent fact accurately when presenting qualifications, experience, or other information for solicitation of employment including facts about employers, employees, associates, or past accomplishments.
6. **CONDUCT** their professional relations by the highest standards of integrity and avoid compromise of their professional judgment by conflicts of interest. When becoming aware of professional misconduct by a BCSP certificant, take steps to bring that misconduct to the attention of the Board of Certified Safety Professionals.
7. **ACT** in a manner free of bias, discrimination or harassment on the basis of race, color, religion (creed), gender, gender expression, age, national origin (ancestry), disability, marital status, sexual orientation, veteran status, or any characteristic protected by the law of the applicable jurisdiction.
8. **SEEK** opportunities to be of constructive service in civic affairs and work for the advancement of the safety, health, and well-being of their community and their profession by sharing their knowledge and skills.

The above Code of Ethics and Standards were approved by the BCSP Board of Directors on January 1, 2023. These ethics and standards became effective January 1, 2023.

Reference

1. Complete Guide to Safety Certification. April 2024. Board of Certified Safety Professionals. Retrieved from: https://online.fliphtml5.com/pbcyp/ijfs/.



Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

Appendix A: BCSP Supplied Equations

Mechanics

$$F = \mu N$$

F = frictional force (newtons)
μ = coefficient of friction
N = newtons

$$F_1 D_1 = F_2 D_2$$

F = force (newtons)
D = distance

$$v = v_o + at$$

v = velocity
v_o = original velocity at the start of acceleration
a = acceleration
t = time (seconds)

$$s = v_o t + \frac{at^2}{2}$$

s = displacement of the object (change in position—normally described in distance from its original position)
v_o = initial velocity
t = time
a = acceleration

$$v^2 = v_o^2 + 2as$$

v = final velocity
v_o = initial velocity
a = acceleration of the object (meters per second)
s = displacement of the object (normally described in distance from the original position)

$$\text{K.E.} = \frac{mv^2}{2}$$

K.E. = kinetic energy (newtons)
m = mass of the object
v = speed of the object (velocity)

$$\text{P.E.} = mgh$$

P.E. = potential energy (joules)
m = mass of the object (kilograms)
g = gravitation acceleration of the earth (9.8 m/s^2)
h = height above earth's surface (meters)

$$\text{P.E.} = \frac{kx^2}{2}$$

P.E. = potential energy (elastic)(joules)
k = spring constant (N/m^2)
x = amount of compression (distance in meters)

$$\rho = mv$$

ρ = momentum
m = mass (kilograms)
v = velocity (meters per second)

$$F = ma$$

F = amount of force
m = mass (kilograms)
a = acceleration (meters per second squared)

$$W = mg$$

W = amount of work done on or to an object due to gravity
m = mass (kilograms)
g = gravity (9.8 m/s^2) (constant)

$$W = Fs$$

W = work done on or to a system (usually in joules or N/m^2) (1 J = 1 N × 1 m)
F = amount of force (newtons)
s = distance (usually meters or feet)

Ergonomic (Revised NIOSH Lifting Equations)

$$\text{Lifting Index (LI)} = \frac{L}{\text{RWL}}$$

LI = Lifting Index
L = object weight
RWL = recommended weight limit

$$\text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM}$$

RWL = recommended weight limit
LC = load constant
HM = horizontal multiplier
VM = vertical multiplier
DM = distance multiplier
AM = asymmetric multiplier
FM = frequency multiplier
CM = coupling multiplier

Heat Stress and Relative Humidity

Indoor (no solar load)

$$0.7\ \text{WB} + 0.3\ \text{GT}$$

Outdoors (with solar heat load)

$$0.7\ \text{WB} + 0.2\ \text{GT} = 0.1\ \text{DB}$$

WB = wet-bulb temperature
GT = globe temperature
DB = dry-bulb temperature

Concentrations of Vapors and Gases

$$\text{ppm} = \frac{\frac{\text{mg}}{\text{m}^3} \times 24.45}{\text{MW}}$$

ppm = parts per million
mg/m^3 = measured mg/m^3 of the contaminant
MW = molecular weight of the contaminant
24.45 = constant = 1 g-mol

$$TLV_m = \frac{1}{\left(\frac{f_1}{TVL_1} + \frac{f_2}{TVL_2} + \cdots \frac{f_n}{TVL_n}\right)}$$

f = fraction of chemical (weight percent of liquid mixture)
TLV = threshold limit value of the chemical

$$LFL_m = \frac{1}{\left(\frac{f_1}{LFL_1} + \frac{f_2}{LFL_2} + \cdots \frac{f_n}{LFL_n}\right)}$$

f = fraction of chemical in the mixture
LFL = lower flammability limit

$$PV = nRT$$

P = absolute pressure (atm)
V = volume (liters)
n = number of molecules (moles)
R = universal gas constant (derived from table)
T = temperature (Rankine or Kelvin)

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

P = absolute pressure (atm)
V = volume of gas (liters)
T = temperature of gas (Kelvin temperature scale)

Ventilation

$$Q = VA$$

Q = volumetric flow rate (cfm)
V = velocity of the air (fpm)
A = cross-sectional area of the duct (sf)

$$V = 4005\,C_e\sqrt{SP_h}$$

V = velocity (fpm)
C_e = coefficient of entry loss
SP_h = static pressure of the hood (″wg)

$$SP_{fan} = SP_{out} - SP_{in} - VP_{in}$$

SP = static pressure (″wg)

$$SP_h = VP + h_e$$

SP_h = static pressure of the hood (″wg)
VP = duct velocity pressure (″wg)
h_e = overall hood entry loss (″wg)

NOTE: When calculating for SP_h, it is understood that the static pressure of the hood is always positive; therefore, in this equation, the SP_h should be interpreted as the absolute value.

$$h_e = \frac{\left(1 - C_e^2\right) VP}{C_e^2}$$

h_e = hood entry loss (″wg)
C_e = coefficient of entry loss
VP = velocity pressure of duct (″wg)

$$Q = \frac{403 \times 10^6 \times SG \times ER \times K}{MW \times C}$$

Q = actual ventilation rate (cfm)
SG = specific gravity of volatile liquid
ER = evaporation rate of liquid (pints per minute)
K = design distribution constant to allow for incomplete mixing of contaminant air (1–10)
MW = molecular weight of liquid
C = desired concentration of gas or vapor at time t (ppm)—normally the TLV or PEL

$$V = 4005\sqrt{VP}$$

V = velocity of air (fpm)
VP = velocity pressure (″wg)

$$TP = SP + VP$$

TP = total pressure (″wg)
SP = static pressure (″wg)
VP = velocity pressure (″wg)

$$V = \frac{Q}{10x^2 + A}$$

V = velocity (fpm)
Q = flow rate (cfm)
x = source distance from hood opening (feet) (the equation is only accurate for a limited distance of 1.5 times the diameter of a round duct or the side of a rectangle or square duct)
A = area (sf)

$$C_e = \sqrt{\frac{VP}{SP_h}}$$

C_e = coefficient of entry loss
VP = velocity pressure of the duct (″wg)
SP_h = static pressure of the hood (″wg)

$$Q' = \frac{G}{C}$$

Q' = the effective rate of ventilation corrected for incomplete mixing (cfm) ($Q' = Q/K$)
K = design distribution constant to allow for incomplete mixing of contaminant air (1–10)
G = generation rate (cfm)

$$G = \frac{\text{constant} \times \text{specific gravity} \times \text{evaporation rate}}{\text{molecular weight}}$$

$$C = \frac{G}{Q'}\left(1 - e^{\frac{Nt}{60}}\right)$$

C = concentration at a given time (ppm)
G = rate of generation of contaminant (cfm)
Q' = (Q/K)
K = design distribution constant (1–10)
Q = flow rate (cfm)
Nt = number of air changes

$$\ln\left(\frac{C_2}{C_1}\right) = -\frac{Q'}{V}(t_2 - t_1)$$

C_1 = the measured concentration
C_2 = the desired concentration
Q' = (Q/K)
K = design distribution constant (1–10)
Q = flow rate (cfm)
$t_2 - t_1$ = time interval or $\Delta\, t$
V = volume of space (ft^3)

$$\ln\left(\frac{G - Q'C_2}{G - Q'C_1}\right) = -\frac{Q'(t_2 - t_1)}{V}$$

G = rate of generation of contaminant (cfm)
Q' = (Q/K)
$t_2 - t_1$ = time interval or A
C_1 = the measured concentration
C_2 = the desired concentration
V = volume of space (ft^3)

$$C = \frac{P_v \times 10^6}{P_b}$$

C = concentration (ppm)
P_v = pressure of chemical (mm Hg)
P_b = barometric pressure (mm Hg)

Engineering Economy

$$F = P(1 + i)^n$$

F = future value of money
P = present value of money (principal)
i = interest rate (decimal)
n = number of years

$$P = F(1 + i)^{-n}$$

P = present worth of money (principal)
F = future worth (or savings)
i = interest rate (decimal)
n = number of years

$$F = A\left(\frac{(1+i)^n - 1}{i}\right)$$

F = future value of money
A = each payment ($)
i = interest rate (decimal)
n = number of periods

$$A = F\left(\frac{i}{(1+i)^n - 1}\right)$$

A = yearly payment of loan
F = future value of loan
i = interest

$$P = A\left(\frac{(1+i)^n - 1}{i(1+i)^n}\right)$$

P = present worth of money ($)
A = period payment amount ($)
i = annual percentage rate (decimal)
n = number of periods

$$\boldsymbol{A} = \boldsymbol{P}\left(\frac{\boldsymbol{i}(1+\boldsymbol{i})^n}{(1+\boldsymbol{i})^n - 1}\right)$$

A = period payment amount ($)
P = present worth of money
i = annual percentage rate (decimal)
n = number of periods

Reliability

$$P_f = 1 - R(t)$$

P_f = probability of failure
$R(t)$ = reliability

$$R(t) = e^{-\lambda t}$$

$R(t)$ = reliability
t = time in which reliability is measured
λ = number of failures divided by the number of time units during which all items were exposed

$$P_f = (1 - P_s)$$

P_f = probability of failure
P_s = probability of success or reliability of the system

Noise

$$I = \frac{p^2}{\rho c}$$

I = sound intensity (W/m^2)
p = sound pressure level (N/m^2)
ρ = the density of the medium (in air, 1.2 kg/m^2)
c = the speed of sound (in air, 344 m/s)

NOTE: The equation shown on the exam reference sheet does not show the RMS sound pressure squared. Therefore, it is necessary for you to remember the correction in this equation if performing sound intensity level calculations.

$$L_{pt} = 10\log\left[\sum_{i=1}^{N} 10^{\left(\frac{L_{pi}}{10}\right)}\right]$$

L_{pt} = combined sound pressure level
L_{pi} = individual measured sound pressure level

$$L_w = 10 \log_{10} \frac{W}{W_o}$$

L_w = sound power level (dB)
W = acoustic power (W)
W_o = reference acoustic power (10^{-12} W)

$$L_p = 20 \log_{10} \frac{p}{p_o} \text{dB}$$

L_p = sound pressure level (dB)
p = measured sound pressure level (N/m^2)
p_o = reference sound pressure level (0.00002 N/m^2)

$$T = \frac{8}{2^{(L-90)/5}}$$

T = time allowed for exposure
L = sound pressure level (dB)

$$D = 100 \left[\sum_{i=1}^{N} \frac{C_i}{T_i} \right]$$

D = dosage (or effective dose)
C_i = actual exposure time
T_i = allowed exposure time

$$\text{dB}_1 = \text{dB}_o - 20 \log_{10} \left(\frac{d_o}{d_1} \right)$$

dB_o = the original sound level measurement
dB_1 = the calculated sound level measurement at another distance
d_o = the original distance where noise measurement was taken
d_1 = the second distance that you would like to calculate the sound level reading

$$\text{TWA} = 16.61 \log_{10} \left[\frac{D}{100} \right] + 90$$

TWA = time-weighted average
D = dose

$$\text{dB} = 10 \log_{10} \left(\frac{A_2}{A_1} \right)$$

dB = noise reduction in decibels
A_1 = total number of absorption units (sabins) in the room before treatment
A_2 = total number of absorption units (sabins) in the room after treatment

$$\text{NR} = \frac{12.6P\pm^{1.4}}{A}\text{dB / ft}$$

NR = noise reduction (dB per foot of length)
P = perimeter of the duct (inches)
α = absorption coefficient of the lining material at the frequency of interest
A = cross-sectional area of the duct (square inches)

Radiation

Ionizing

$$I_2 = I_1\frac{(d_1)^2}{(d_2)^2}$$

I = intensity of source
d = distance from source

$$S \cong 6CE$$

$$I = I_o e^{-\ x}$$

I = intensity
I_o = initial intensity
μ = linear attenuation coefficient (cm^{-1})
x = shielding thickness (cm)

$$I = \beta I_o e^{-\mu x}$$

I = intensity on the opposite side of the shield
I_o = initial intensity
μ = linear attenuation coefficient (cm^{-1})
x = shielding thickness (cm)
β = radiation scatter "buildup" factor (assume $\beta = 1$)

Nonionizing

$$W = \frac{16P}{\pi D^2} = \frac{4P}{A}$$

W = power density (mW/cm^2)
P = antenna power (mW)
A = effective antenna area (cm^2)
D = diameter of antenna (cm)
A = cross-sectional area of antenna (cm^2)

$$W = \frac{GP}{4\pi r^2} = \frac{AP}{\lambda^2 r^2}$$

W = power density (mW/cm^2)
P = antenna power (mW)
A = effective antenna area (cm^2)
λ = wavelength (cm)
r = distance from antenna (cm)
G = gain $\left(\text{calculated by } G = \frac{4\pi A}{\lambda^2}\right)$. When the gain is used in calculations, the values of the absolute gain must be used: $G = 10^{\frac{g}{10}} = \text{antilog}\,\frac{g}{10}$.

$$E_{\text{eff}} = E_\lambda S_\lambda \Delta_\lambda$$

E_{eff} = effective irradiance
E_λ = spectral irradiance (W/cm^2-nm)
S_λ = power density (W/m^2)
Δ_λ = optical density (dimensionless)

$$c = \lambda f = \frac{\lambda}{T}$$

c = speed of light (3×10^{10} cm/s)
λ = wavelength (cm)
f = frequency (cycles per second)

Appendix B: Conversions and Standards

Length

2.54 cm = 1 inch
25.4 mm = 1 inch
12 inches = 1 foot
3 feet = 1 yard
5280 feet = 1 mile
1760 yards = 1 mile
1609 meters = 1 mile
0.868 nautical miles = 1 US mile

Area

1 sq. in. = 6.452 sq. cm
1 sq. in. = 6452 sq. mm
1 sq. ft = 144 sq. in.
1 sq. ft = 0.09290 sq. m
1 sq. yd. = 9 sq. ft

Volume

1 cu. cm = 1 mL
1 cu. in. = 16.39 cu. cm

1 cu. ft = 1728 cu. in.
1 cu. ft = 0.02832 cu. m
1 L = 1.057 quarts (US)
0.9463 L = 1 quart
1 US gallon = 0.1337 cu. ft
1 US gallon = 0.8327 Imperial gallons

Time

60 s = 1 min
60 min = 1 h
24 h = 1 day
3600 s = 1 h

Mass and Weight

16 ounces = 1 lb
1 g = 1000 mg
1 lb = 2.205 kg
1 ton (US) = 2000 lb
1 tonne (metric ton) = 1000 kg
1 dram = 1771.85 mg

Energy

1 cal = 0.003968 Btu
1 cal = 4.187 J
1 Btu = 252 cal
1 J = 0.2388 cal

Velocity

1 ft/s = 0.3048 m/s
1 ft/s = 0.8618 mi/h
1 ft/s = 0.5921 knots
1 m/s = 3.281 ft/s
1 m/s = 2.237 mi/h
1 mi/h = 0.4470 m/s
1 mi/h = 1.467 ft/s
1 knot = 0.5148 m/s
1 knot = 1.151 mi/h
1 knot = 1.689 ft/s

Density

1 lb/cu. ft = 0.01602 cu. cm
1 g/cu. cm = 62.42 lb/cu. ft
1 g/cu. cm = 1000 kg/cu. m
1 kg/cu. m = 0.001 g/cu. cm

Pressure

1 psia = 6.895 kN/m^2
1 psia = 0.0680 atm
1 psia = 27.67 in. H_2O
1 psia = 51.72 mm Hg
1 psig = ADD 14.7 psia
1 mm Hg (Torr) = 0.01934 psia
1 mm Hg (Torr) = 0.1333kN/m^2
1 in. H_2O = 0.2491 kN/m^2
1 kg/cm^2 = 735.6 mm Hg (Torr)
1 in. H_2O = 0.3614 psia

1 kg/cm^2 = 0.9678 atm
1 atm = 101.3 kN/m^2
1 kg/cm^2 = 14.22 psia
1 atm = 14.70 psia
1 bar = 100 kN/m^2
1 kN/m^2 = 0.1450 psia
1 bar = 0.9869 atm
1 kN/m^2 = 0.009869 atm
1 bar = 1.020 kg/cm^2

Heat Capacity

1 Btu/lb/°F = 1 cal/g/°C
1 Btu/lb/°F = 4187 J/kgK
1 J/kgK = 0.0002388 Btu/lb/°F
1 cal/g/°C = 1 Btu/lb/°F

Concentration

1 ppm = 1 mg/L
1 mg/L = 1 ppm
1 $mg/m^3 = 1 \times 10^{-9} g/cm^3$
1 $g/cm^3 = 1 \times 10^9$ mg/m^3
1 g/m^3 = 62.42 lb/ft^3
1 lb/ft^3 = 0.01602 g/cm^3

SI Conversion Factors

From	Multiply by	To Find
Length		
Inches	25.4	Millimeters
Feet	0.305	Meters
Yards	0.914	Meters
Miles	1.61	Kilometers
Area		
Square inches	645.2	Square millimeters
Square feet	0.093	Square meters
Square yards	0.836	Square meters
Acres	0.405	Hectares
Square miles	2.59	Square kilometers
Volume		
Fluid ounce	29.57	Milliliters
Gallons	3.785	Liters
Cubic feet	0.028	Cubic meters
Cubic yards	0.765	Cubic meters
Mass		
Ounce	28.35	Grams
Pounds	0.454	Kilograms
Temperature		
Fahrenheit	5(°F – 32)/9	Celsius
Celsius	9(°C + 32)/5	Fahrenheit
Celsius	°C + 273	Kelvin
Fahrenheit	°F + 460	Rankine
Pound-force	4.45	Newtons
Pound-force/square inch	6.89	Kilopascals
Illumination		
Foot-candle	10.76	Lux
Foot-lambert	3.426	Candela/square meter

Standards and Constants

Physical Constants

Acceleration of gravity = 32.2 ft/s^2 = 9.8 m/s^2
Velocity of light = 3.0×10^8 m/s
Planck's constant = 6.626×10^{-34} J·s
Avogadro's number = 6.024×10^{23}/g-mol

Radiation

1 rad = 10^{-2} gray
1 rem = 10^{-2} sievert
1 curie = 3.7×10^{10} becquerel
1 becquerel = 1 disintegration/s

Density of Water

1 g/cm^3 = 1.94 $slugs/ft^3$
Weight density = 62.4 lb/ft^3
1 US gallon of H_2O = 8.345 lb

Angles

1 radian = $180°/\pi$

Light

1 candela = 1 lumen/steradian
1 foot-candle = 10.76 $candela/m^2$ = 10.76 lux

Magnetic Fields

1 tesla = 10,000 gauss

Energy

1 British Thermal Unit (Btu) = 1055 J
1 faraday = 9.65×10^4 coulombs
1 g-cal = 4.19 J
1 g-mol at 0°C and 1 atm = 22.4 L
1 g-mol at 25°C and 1 atm = 24.45 L
1 ampere-hour = 3600 coulombs
1 W = 1 J/s = 1 A × 1 V
1 kwh = 3.6×10^6 J

Standards

STP (physical science) = 0°C and 1 atm
STP (ventilation) = 70°F and 1 atm
Air density = 0.075 lb/ft^3 at 70°F and 1 atm
STP (industrial hygiene) = 25°C and 1 atm

Appendix C: OSHA Regional and Area Offices

OSHA Regional Offices

Region 1 (ME, NH, MA, RI, CT, VT)

JFK Federal Building, Room E340
Boston, MA 02203
TEL: (617) 565-9860
FAX: (617) 565-9827

Region 2 (NY, NJ, PR, VI)

201 Varick Street, Room 670
New York, NY 10014
TEL: (212) 337-2378
FAX: (212) 337-2371

Region 3 (DC, DE, MD, PA, VA, WV)

US Department of Labor/OSHA
The Curtis Center-Suite 740 West
170 S. Independence Mall West
Philadelphia, PA 19106-3309
TEL: (215) 861-4900
FAX: (215) 861-4904

Region 4 (KY, TN, NC, SC, GA, AL, MS, FL)

61 Forsyth Street, SW
Room 6T50
Atlanta, GA 30303
TEL: (404) 562-2300
FAX: (404) 562-2295

Region 5 (IL, IN, MI, MN, OH, WI)

230 South Dearborn Street, Room 3244
Chicago, IL 60604
TEL: (312) 353-2220
FAX: (312) 353-7774

Region 6 (AR, LA, NM, OK, TX)

525 Griffin Street, Suite 602
Dallas, TX 75202
TEL: (972) 850-4145
FAX: (972) 850-4149
FAX: (972) 850-4150 FSO

Region 7 (IA, KS, MO, NE)

Two Pershing Square Building
2300 Main Street, Suite 1010
Kansas City, MO 64108-2416
Phone: (816) 283-8745
Voice: (816) 283-0545
FAX: (816) 283-0547

Region 8 (CO, MT, ND, SD, UT, WY)

1999 Broadway, Suite 1690
Denver, CO 80202
TEL: 720-264-6550
FAX: 720-264-6585

Region 9 (CA, NV, AZ)

90 7th Street, Suite 18100
San Francisco, CA 94103
(415) 625-2547 (Main Public—8:00 a.m. to 4:30 p.m. Pacific)
(800) 475-4019 (for Technical Assistance)
(800) 475-4020 (for Complaints—Accidents/Fatalities)
Note: **The 800 number for Complaints—Accidents/Fatalities is Regional only.**
(800) 475-4022 (for Publication Requests)
FAX: (415) 625-2534

Region 10 (AK, ID, OR, WA)

1111 Third Avenue, Suite 715
Seattle, WA 98101-3212
TEL: (206) 553-5930
FAX: (206) 553-6499

OSHA Area Offices

Alabama

Birmingham Area Office

Medical Forum Building
950 22nd Street North, Room 1500
Birmingham, AL 35203
TEL: (205) 731-1534
FAX: (205) 731-0504

Mobile Area Office

1141 Montlimar Drive, Suite 1006
Mobile, AL 36609
TEL: (251) 441-6131
FAX: (251) 441-6396

Alaska

Anchorage Area Office

Scott Ketcham, Area Director
U.S. Department of Labor—OSHA
222 W. 8th Avenue, Room A14
Anchorage, AK 99513
Mailing Address:
Anchorage Area Office
Scott Ketcham, Area Director
U.S. Department of Labor—OSHA
222 W. 7th Avenue, Box 22
Anchorage, AK 99513
TEL: (907) 271-5152
FAX: (907) 271-4238

American Samoa

Region IX Federal Contact Numbers

90 7th Street, Suite 18100
San Francisco, CA 94103
(415) 625-2547
(Main Public—8:00 a.m. to 4:30 p.m. Pacific)
(800) 475-4019 (for Technical Assistance)
(800) 475-4020 (for Complaints—Accidents/Fatalities)
Note: **The 800 number for Complaints—Accidents/Fatalities is Regional only.**
(800) 475-4022 (for Publication Requests)
FAX: (415) 625-2534

Arizona

Industrial Commission of Arizona (ICA)

800 W. Washington Street
Phoenix, AZ 85007
Laura L. McGrory**, Director & State Designee**
Arizona Division of Occupational Safety and Health (ADOSH)

Phoenix Office

U.S. Department of Labor—OSHA
Phoenix Federal Building
230 N. 1st Avenue, Suite 202
Phoenix, AZ 85003
TEL: (602) 514-7250
FAX: (602) 514-7251
Darin Perkins**, Director**
Bill Wright**, Assistant Director**
Babak Emami**, Consultation & Training Manager**
TEL: (602) 542-1769

Tucson Office

2675 E. Broadway Blvd. #239
Tucson, AZ 85716
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