

OCCUPATIONAL SAFETY AND HEALTH *SIMPLIFIED* FOR THE CHEMICAL INDUSTRY



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GOVERNMENT INSTITUTES 

Occupational Safety and Health *Simplified* for the Chemical Industry

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Preface

The third of a new Government Institutes series, *Occupational Safety and Health Simplified for the Chemical Industry* is a reference that serves managers, students, and other professionals associated with the chemical industry, who want quick answers to complicated questions, and to assist employers and employees to handle safety hazards and dangers they deal with on a regular basis. This book is an effort to simplify in a single volume everything that those in the chemical industry need to know about applicable Occupational Safety and Health Administration (OSHA) standards, chemical safety, health principles, and workplace applications. Moreover, because it is a reference as well as a text, this handy little book is designed to be consulted routinely—to be taken to job locations as well as the classroom—to help the user understand and make sense of complex OSHA regulations. This text has been written in simple and understandable terms, making it easy to follow for professionals and nonprofessionals alike. However, it is important to note that it is in fact simplified. Compliance with the law can only be achieved by consulting the actual Code of Federal Regulations (CFR)—in this case, 29 CFR 1910 General Industry Standards (the “OSHA bible”)—applicable Department of Transportation (DOT) Hazardous Materials (HazMat) Regulations, and various Environmental Protection Agency (EPA) HazMat regulations dealing with emergency response procedures. While this book gives a simplified and easily understandable version of the regulations, you must go to the regulations themselves in order to ensure complete compliance with the law—and, more importantly, to ensure the protection of employees.

Occupational Safety and Health Simplified for the Chemical Industry includes:

- Basic chemical safety precautions
- How to prevent accidents from the most serious hazards in the chemical manufacturing industry, such as
 - Respiratory hazards from inhalation of chemicals
 - Electrical incidents
 - Slips, trips, and falls
 - Cuts (lacerations)

- Ergonomic hazards
- Eye hazards
- Stored energy hazards
- Material handling hazards
- Infectious disease
- Fire hazards
- Dermatitis
- OSHA's chemical manufacturing standards requirements
- Many of OSHA's chemical manufacturing training requirements
- Eyewash/emergency deluge shower requirements
- How to interpret OSHA's Hazard Communication standard
- A sample Hazard Communication program
- A comprehensive, easy-to-use sample chemical hygiene plan
- A sample chemical safety program to help meet OSHA compliance requirements
- A sample chemical industry emergency response plan

This book is written to help professionals and nonprofessionals associated with the chemical industry to have access to the most current information and should be used as a reference book for quick answers and complicated questions.

It is our hope that through education, use, and referencing of this book by employers, employees, and students that accidents, injuries, and fatalities resulting from chemical exposures in the workplace will be prevented by increasing awareness of the risks that are inherent in the chemical industry and the steps that can and should be taken to minimize them.

Even though accidents can never be eliminated completely, it is our hope that this book will help employers prevent many of the chemical manufacturing injuries and fatalities that occur each year, while at the same time simplifying the OSHA compliance process. However, it is very important to remember that the sole way to ensure compliance with the law is to consult and comply with the regulations set out in the Code of Federal Regulations. The applicable volumes of the CFR can be obtained from Government Institutes or the Government Printing Office.

Frank R. Spellman
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Norfolk, Virginia

PROLOGUE

A Day at the Marketplace

Day rose heavy and hot, but the wind whispered in the field beyond the sod house as if murmuring delightful secrets to itself. A light breeze entered the open windows and gently touched those asleep inside. A finger of warmth, laden with the rich, sweet odor of earth, lightly touched Juju's cheek—rousing her this morning as it had often in her nine years of life. On most days, Juju would lie on her straw mat and daydream, languishing in the glory of waking to another day on Mother Earth. But nothing was normal on this morning. This day was different—full of surprises and excitement. Juju and her mother Lanruh were setting out on an adventure today—and Juju couldn't wait.

As she stood at the foot of her makeshift bed, Juju swiftly tucked the folds of thin fabric around her slender waist and let the fall of cloth hang to her feet. She pulled her straight black hair tight in a knot at the back of her neck before she draped the end of the sari over her head.

While Juju dressed, Lanruh performed the same ritual in her small room, next to Juju's. Lanruh was excited about the day's events, too—she knew Juju was thrilled and she was delighted by her daughter's pleasure and excitement. Lanruh chuckled to herself as she remembered the many times over the last few years that Juju had begged to be included, to be taken to the Grand Market in town. Lanruh understood Juju's excitement. Going into the town, taking it all in—the market thrilled Lanruh, too.

As they stepped out of the sod house and onto the dirt road, the scented breeze that had touched Juju's cheek earlier greeted them. They walked together, hand in hand, toward town, three kilometers to the south.

Juju bubbled with anticipation, but she held it in, presenting the calm, serene face expected of her. Even so, every nerve in her young body reverberated with excitement.

As they walked along the road, Juju, fascinated by everything she saw, took in everything they passed in this extension of her small world. People and cattle everywhere—she had never seen so many of either! Her world had grown, suddenly—and it felt good to be alive.

As they neared town, Juju could see tall buildings. How big and imposing they were—and so many of them! In town, in places they passed, some of the streets were

actually paved. Juju had never seen paved streets. This trip to town was her first city experience, and she was enthralled by all the strange and wonderful sights. As they walked along the street leading to the marketplace, Juju was overawed by the tall buildings and warehouses. “What can they all be used for?” she wondered. Some of them had signboards above their doors, but little good that did for Juju—she couldn’t read.

The light breeze had escorted Juju and Lanruh since they left home, and it was still with them as they turned toward the market. Juju could see the entrance and the throngs of bustling people ahead, and her eyes snapped with excitement.

Suddenly, with one breath of that sweet air (was it the same sweet air that had touched her into waking only two hours earlier?), Juju began coughing. She clutched her throat with both hands, falling to her knees in sudden agony. Her mother had also fallen, gasping for air. The breeze that had begun her day now ended it—delivering an agent of death. But Juju didn’t have time to realize what was happening. She couldn’t breathe. She couldn’t do anything, except die—and she did.

Juju, Lanruh, and over two thousand others died within a very few minutes.

Those who died that day—December 3, 1984—never knew what killed them. The several hundred others who died soon after did not know what killed them, either.

The several thousand inhabitants who lived near the marketplace, near the industrial complex, near the pesticide factory, near the chemical spill, near the release point of that deadly toxin—knew little, if any of this. They knew only death and killing sickness that sorry day.

Those who survived that day were later told that a deadly chemical had killed their families, their friends, their neighbors, their acquaintances. They were killed by a chemical spill that today is infamous in the journals of hazardous materials incidents. Today, this incident is studied by everyone who has anything to do with chemical production and handling operations. We know it as Bhopal.

The dead knew nothing of the disaster—and their deaths were the result.

Frank R. Spellman (2006)

CHAPTER 1

Introduction

Every now and then when your life gets complicated and the weasels start closing in, the only cure is to load up on heinous chemicals and then drive like a bastard from Hollywood to Las Vegas . . . with the music at top volume and at least a pint of raw ether.

Hunter S. Thompson (1939–2005),
Fear and Loathing in Las Vegas

Recently, when it came time to decide on a textbook to use for a course on occupational safety and health in the chemical industry, we were surprised to find out that currently there are few to no texts on the subject available. It is for this reason (and others) that this text was written. Specifically, as the title (and not the opening statement by Hunter S. Thompson) implies, this book deals with Occupational Safety and Health Administration (OSHA) occupational safety and health requirements for the chemical industry.

Occupational Safety and Health Simplified for the Chemical Industry is targeted both toward a specific audience (students) and a more general audience (others):

- Professionals (especially environmental practitioners) who need a quick review of chemical safety and health principles and applications
- Nonprofessionals who need an information source
- General readers who are not satisfied with their knowledge level in their specific area of expertise alone but prefer to add knowledge on the basic tenets of chemical safety to their repertoire

Key features of the text include:

- The necessary jargon, concepts, and key concerns of the chemical industry as it relates to regulatory compliance with OSHA
- Interesting and up-to-date applications with numerous real-life examples
- Easy-to-understand language with points of caution/interest (key and important points) to avoid misunderstanding or misapplication

- Common examples to allow the reader to understand the context of the information and its relevance to maintaining a good safety and health profile in the chemical industry
- Explanations of concepts without mathematics and with easy-to-understand physical/chemical science concepts
- Insights for those entering the environmental safety and health profession and/or the chemical industry

Why Study Chemical Safety?

Why should we care about chemical safety? Isn't it enough to know that we don't want unnecessary chemicals in or on our food or harmful chemicals in our air, water, or soil?

Chemicals are everywhere in our environment. The vast majority of these chemicals are natural. The chemist often copies from nature to create new substances that are often superior to and cheaper than natural materials. It is human nature to make nature serve us. Without chemistry (and the other sciences), we are at nature's mercy.

Environmental professionals must also learn the laws of chemistry and how to use them. But they must know more. Environmental professionals must know the ramifications of chemistry when it is out of control. Chemistry properly used can perform miracles. Out of control, chemicals and their effects can be devastating. In fact, many OSHA regulations dealing with chemical safety and emergency response procedures for chemical spills resulted because of catastrophic events involving chemicals. For example, OSHA's 1910.1200 standard, Hazard Communication, and its 1910.119 standard, Process Safety Management (PSM), got their genesis because of the horrific results of the Bhopal, India, incident described in the prologue, which occurred just after midnight on December 3, 1984.

The Bhopal incident was caused when a U.S.-based Union Carbide Corporation pesticide plant accidentally released approximately 40 metric tons of methyl isocyanate (MIC) into the atmosphere. The incident was a catastrophe for Bhopal, with an estimated 2,000 deaths, 100,000 injuries, and significant damage to livestock and crops. The long-term health effects from such an incident are difficult to evaluate; the International Medical Commission on Bhopal estimated that as of 1994 more than 50,000 people remained partially or totally disabled (House of Representatives 1984).

Important Point: Methyl isocyanate is an organic chemical that is used in the production of pesticides. Methyl isocyanate, commonly referred to as MIC, is extremely toxic to humans. Short-term exposure may cause death or adverse health effects, including pulmonary edema (respiratory inflammation), bronchitis, bronchial pneumonia, and reproductive effects.

The ultimate cause of the Bhopal incident remains in contention. However, as mentioned, the Bhopal incident is cited as a factor in the development and implementation of U.S. environmental legislation and regulations, including the creation of the U.S. Chemical Safety Board.

Although the Bhopal incident was a wake-up call for the U.S. Congress and for OSHA, the Environmental Protection Agency (EPA), and environmental practitioners, many environmental professionals felt that a “Bhopal-like incident” could not occur in the United States. It is rather ironic that during the entire regulatory clamor generated by the Bhopal incident and claims that such an incident could not occur in the United States, an accidental chemical release did occur in the United States in August 1985. This incident also involved a Union Carbide plant. The plant, located in Institute, West Virginia, released a cloud of methylene chloride and aldicarb oxide that affected four neighboring communities and led to the hospitalization of over 100 people. In the wake of this and the Bhopal incident, the U.S. Congress passed the 1986 Emergency Planning and Community Right to Know Act, implemented by the EPA.

The tragedy of the Bhopal incident and its ramifications are best stated by the Union Carbide Corporation:

The legacy of those killed and injured [at Bhopal] is a chemical industry that adheres voluntarily to strict safety and environmental standards—working diligently to see that an incident of this nature never occurs again. (2002)

Hazardous chemical incidents are not the only area of concern for environmental professionals and workers in the chemical industry (and for the rest of us). The fact is, almost every pollution problem we currently face has a chemical basis, and many of the on-the-job injuries encountered are the result of chemical exposure of some type.

In regard to the impact chemicals can have on the environment, for example, during the 1970s, the media began reporting about a new environmental hazard: acid deposition. They described it in grim terms as “acid rain” and in even grimmer terms as “death from the sky.”

In regard to water pollution, reports pointed out that water pollutants have the ability to harm aquatic life, threaten human health, or result in the loss of recreational or aesthetic potential. Surface water pollutants come from industrial sources, nonpoint sources, municipal sources, background sources, and other/unknown sources. Out of the eight chief water pollutants—biochemical oxygen demand, nutrients, suspended solids, pH, oil and grease, pathogenic microorganisms, toxic pollutants, and nontoxic pollutants—all, in one way or another, are linked to chemistry and the chemical industry.

In the early 1990s, a global assessment of soil degradation was conducted for the United Nations Environment Programme. This study pointed out that in recent decades nearly 11 percent of the Earth’s fertile soil has been so eroded, chemically altered, or physically compacted as to damage its original biotic function (i.e., its ability to process nutrients into a form usable by plants). About 3 percent of soil has been degraded virtually to the point where it can no longer perform that function (World Resources Institute 1992).

Occupational Health and Safety (OH&S) practitioners focus primarily on maintaining the safety and good health of workers. However, as pointed out above, they also have an obligation to protect the public and the environment from chemical-generated

pollution problems such as the greenhouse effect, ozone depletion, toxic wastes, groundwater contamination, air pollution, and acid rain, to mention a few. To deal effectively with these kinds of chemical-based problems, OH&S professionals must have a strong background in OSHA and EPA regulations and at least a rudimentary understanding of the basic concepts of environmental protection (including exposure to chemicals in the workplace).

This book focuses on chemical safety as it relates to workers in the chemical industry. It presents the major concepts of chemical safety, and it concentrates on how some information on chemistry is applied to real-world decision making—in making the workplace a safer place to work. For example, readers of this book will be provided with a very basic understanding of the physical properties of chemicals so they can comprehend key safety and health data found in Material Safety Data Sheets (MSDSs), laboratory analytical reports, and the chemistry behind safety and environmental regulations. They will also gain a better understanding of key OSHA safety and health programs such as Hazard Communication, Process Safety Management, and the Laboratory Safety and Chemical Hygiene Plan. This is a basic “applications-oriented” text, with the emphasis on the word “basic.”

What You Should Know about Chemical Safety

Even if you do not work in the chemical industry, you should know:

- What the chemicals are in your work area
- Whether they are harmful or hazardous, and if so,
- What are the hazards, and
- How you can protect yourself.

Chemicals are at the heart of our technology-based society. They are used in connection with the production and manufacturing of a host of products. Among the most common products produced by chemical industry workers are plastics, rubber, leather, paper, textiles, paints, fertilizers, pesticides, solvents, detergents, fuels, medicines, automobiles, televisions, building materials, electronics, and sporting equipment. Workers who produce chemical products make it possible for us to experience the trappings of “the good life.” To eliminate chemicals from our society would not only be impractical, it would be undesirable. Instead, to reduce the loss of lives and property and protect workers and the environment from the hazards of chemicals, we must learn to live safely in their presence and effectively control the emergencies they may produce.

The problem is that chemicals are so much a part of our chemical and nonchemical industry work environment we often forget that they can be harmful. Even the office in a chemical manufacturing company with little more than computers, desks, and books can include liquid sprays and powders that are harmful to your health if inhaled or ingested. The good news is that most of the harmful office materials are not a risk if used properly.

What Makes a Chemical Hazardous?

Chemicals are hazardous if they are:

- **Corrosive:** capable of eating away materials and destroying living tissue when contact occurs
- **Explosive and/or reactive:** capable of causing an explosion or releasing poisonous fumes when exposed to air, water, or other chemicals
- **Ignitable:** capable of burning or causing a fire
- **Radioactive:** capable of damaging and destroying cells and chromosomal material (known to cause cancer, mutations, and fetal harm)
- **Toxic:** poisonous, either immediately (acutely toxic) or over a long period of time (chronically toxic)

Chemicals can also be characterized by their physical hazards:

- **Combustible liquid:** a liquid having a flashpoint at or above 100°F (37.8°C), but below 200°F (93.3°C)
- **Compressed gas:** a gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C); 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; or a liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C)
- **Explosive:** a chemical that causes a sudden release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature
- **Flammable:** a chemical that falls into one of the following categories:
 - **Aerosol, flammable:** an aerosol that yields a flame when ignited
 - **Gas, flammable:** a gas that at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less; or a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12 percent by volume, regardless of the lower limit
 - **Liquid, flammable:** any liquid having a flashpoint below 100°F (37.8°C)
 - **Solid, flammable:** a solid, other than an explosive, 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
- **Organic peroxide:** 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 has been replaced by an organic radical. Organic peroxides are oxidizers and fuels in one, and are therefore unstable and potentially explosive. “Peroxidizable” means a chemical that will form organic peroxide when exposed to air.
- **Oxidizer:** a chemical other than an explosive that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases

- **Pyrophoric:** a chemical that will ignite spontaneously or explode in air at a temperature of 130°F (54.4°C) or below
- **Unstable (reactive)** : 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 shocks, pressure, or temperature
- **Water-reactive:** a chemical that reacts with water to release a gas that is either flammable or presents a health hazard

How Do I Know If a Chemical Is Hazardous?

EPA and OSHA require that products containing hazardous chemicals capable of harming the environment or consumers, or causing hazardous, dangerous reactions in the workplace (possibly causing harm to workers) to be properly labeled. For instance, the EPA's Federal Hazardous Substances Act of 1960 established specific labeling requirements for consumer products containing hazardous chemicals. If a product contains a hazardous chemical, the front label must include a warning and a description of the hazard. Under OSHA's 29 CFR 1910.1200 Hazard Communication Program (referred to as the HazCom/Employee Right-to-Know Act), employers must label all workplace chemical hazards.

The American National Standards Institute (ANSI) is the organization responsible for publishing the ANSI Z535 series of standards. The ANSI Z535.4 Standard, titled Product Safety Signs and Labels, defines the content for a safety label:

A product safety sign or label should alert persons to a specific hazard, the degree or level of hazard seriousness, the probable consequence of involvement with the hazard, and how the hazard can be avoided. (ANSI Z535.4-1998)

The ANSI levels of chemical hazards are identified using *signal* words:

DANGER: substances that are extremely flammable, corrosive, or highly toxic

POISON: substances that are highly toxic

CAUTION/WARNING: substances that are moderately or slightly toxic

NOTICE: the preferred signal word to address practices not related to personal injury

Did You Know?

Accident-prevention signs (danger, warning, caution, and notice) are specified in OSHA's 29 CFR 1910.145.

Federal Safety Regulators: The Chemical Industry

Although this book primarily deals with OSHA's occupational safety and health requirements for workers in the chemical industry, it is important to recognize that many safety and health regulations are affected by federal laws. The federal statutes listed in table 1.1 affect the manner by which manufacturers identify the contents of products

Table 1.1. Federal Laws that Affect Workers Who Produce Household Chemical Products

<i>Federal Statute</i>	<i>Responsible Agency</i>	<i>Authorization</i>
Federal Hazardous Substances Act	Consumer Product Safety Commission (CPSC)	Requires that certain hazardous household products bear cautionary labeling to alert consumers to the potential hazards that those products present and to inform them of the measures they need to adopt to protect themselves from those hazards
Federal Food, Drug, and Cosmetic Act	U.S. Food and Drug Administration (FDA)	Ensures that foods are safe to eat, drugs are safe and effective, and packaging and labeling of foods, drugs, and cosmetics are truthful and informative
Federal Insecticide, Fungicide, and Rodenticide Act	U.S. Environmental Protection Agency (EPA)	Regulates the manufacture, use, and disposal of pesticides
Toxic Substances Control Act	U.S. Environmental Protection Agency (EPA)	Requires pre-market evaluation of all new chemical products other than food additives, drugs, pesticides, alcohol, and tobacco; regulates existing hazards not covered by other federal laws dealing with toxic substances
Federal Alcohol Administration Act	Bureau of Alcohol, Tobacco, and Firearms (ATF)	Includes ensuring that distilled spirits (beverage alcohols), wines, and malt beverages intended for non-industrial use are safe for consumption, and their packaging and labeling are truthful and informative

sold to consumers. However, it is important to point out that these statutes not only apply to manufacturers in warning the consumer of potential hazards but also serve (indirectly in many cases) to warn workers of hazards. It is also important to remember that if a manufactured product is potentially hazardous to the consumer it may doubly affect the safety and health of workers on the front lines—that is, manufacturing production workers.

OSHA

In 1970, President Richard M. Nixon signed into law the Occupational Safety and Health Act (OSH Act). The act is a federal statute that aims to protect employees in the workplace from occupational illness and injuries caused by exposure to biological and physical hazards and hazardous chemicals. When Congress passed this act, it empowered the Occupational Safety and Health Administration (OSHA) to regulate certain aspects of the workplace, thereby reducing or eliminating the incidence of chemically induced occupational illnesses and injuries.

Throughout the text we will refer to OSHA regulations as they apply to the subject area being discussed. However, for the time being, during this introduction, it is important to point out the significance of Section 5 duties under 29 USC 654 OSH Act of 1970. The following is commonly called OSHA's General Duty Clause:

OSH Act Section 5. Duties

- (a) Each employer—
 - (1) shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;
 - (2) shall comply with occupational safety and health standards promulgated under this Act.
- (b) Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct.

When hazardous chemicals are present in the workplace, OSHA requires employers to limit employee exposure to certain permissible limits averaged over the eight-hour (time weighted average—TWA) workday. Although these limits are established by OSHA, on occasion the National Institute for Occupational Safety and Health (NIOSH) recommends a revision of the limits based upon its own research efforts. Again, under the General Duty Clause of the OSH Act, it is the responsibility of OSHA and NIOSH to ensure that employers provide every working individual with a safe and healthful working environment.

Eugene Meyer (2005) points out that in 1983, OSHA first enacted a standard that sets minimum requirements to which employers must adhere for communicating information to workers; as mentioned earlier, it is known as the Hazard Communication

Standard (often referred to as HazCom or the Right-to-Know Law). Briefly, its intent is to assure workers of their right to know about the hazards associated with chemicals to which they are being exposed in their places of employment. This law prohibits employers from directing workers to handle hazardous chemicals without first training the workers on the potential hazards involved; workers must also be trained on how to protect themselves from the chemical hazards. This law applies to all chemical substances known to be present within the workplace, chemicals to which workers could be exposed under normal working conditions, and chemicals to which workers could be exposed in an emergency.

Did You Know?

Twenty-four states, Puerto Rico, and the Virgin Islands have OSHA-approved state plans and have adopted their own standards and enforcement policies. For the most part, these states adopt standards that are identical to federal OSHA standards. However, some states may have adopted different standards applicable to this topic or may have different enforcement policies.

How Can I Find Specific OSHA Standards?

The best way to find a particular OSHA standard is to obtain a copy of one of the volumes of what we call the “OSHA bible,” that is, the title 29 CFRs—29 CFR 1910 (General Industry Standards), 29 CFR 1926 (Construction Standard), 29 CFR 1915 (Shipyard Standard), 29 CFR 1918 (Longshoring Standard), 29 CFR 1928 (Agriculture), and others. The volume you want to select, of course, will depend on the type of work being performed in your industry. When you select the 29 CFR that applies to you, you do not have to read the entire volume, but you will need to read a particular standard at some point in time. Many OSHA standards are vague and ambiguous, lengthy, and complex. Part of the vagueness and ambiguity is derived from their sources. When the OSH Act was signed into law in 1970, Congress gave OSHA two years to put together the OSHA bible (29 CFRs). OSHA literally took custody of many safety principles and practices that were being used at that time by authoritative and professional agencies. Many of these vintage 1970 or earlier standards still make up more than 90 percent of the 29 CFRs. OSHA standards are also vague and ambiguous because many of them are open to personal interpretation. Based on personal experience, when an organization is cited based on vague and ambiguous findings, most citations end up being thrown out of a court of law. But this can be an extremely expensive process. Reading OSHA standards is complicated because they are not presented in a user-friendly format. That is, they are written in small print and are not separated into subsections by some readily identifiable method.

This is not to say that all OSHA standards are not arranged in the same format or numbering system, because they are. The key is to learn and to understand the format; once this is done, locating particular subsections of a standard will be easier.

As mentioned, each OSHA regulation is preceded by “Title 29 CFR.” Individual parts of Title 29 are designated by a four-digit number (for example, 1926, 1915, 1928, etc.). That “part” designation is the first four numbers of all OSHA standards. A period follows the first four digits. Following that period, each standard is listed in numerical order beginning with number 1. Thus 29 CFR 1910.1 refers to Title 29, Part 1910, and Section 1.

The number following the period is the designation given to a particular OSHA standard. In many cases, it will be followed by a name—for example, §1910.1200, Hazard Communication. There will then follow various subsections of the standard. They are designated by letters and numbers, all of which are in parentheses. The first subsection is (a)—for example, §1910.1200(a). Other major subsections will be similarly designated in alphabetical order—§1910.1200(b), §1910.1200(c), and so on. However, each of them often has its own subsections. And those subsections, in turn, have their subsections. The subsections are arranged and designated as follows:

- First group: alphabetically by lower-case letters; for example, (a)
- Second group: numerically; for example, (1), (2), (3)
- Third group: numerically by roman numerals; for example, (i), (ii), (iii)
- Fourth group: alphabetically by capital letters; for example, (A), (B), (C)

For subsequent groups (if necessary), the order listed above is repeated, but the letter or number is in italics, for example, (*a*), (*1*), and so forth. An example to demonstrate follows.

Listed below are the steps to be taken to locate 29 CFR 1910.1200(b)(6)(ii):

1. Get a copy of Title 29 CFR, Part 1910.
2. Locate §1910.1200 Hazard Communication.
3. Begin with (a) until you find (b).
4. Find (1) under subsection (b). Then look for (6).
5. Once you have located (6), look for roman number (i), then for (ii).

The format and sequence for all OSHA standards is the same. If these steps are followed, you should be able to locate the particular subsection of the standard being sought.

Specific OSHA/Federal Standards Related to Chemical Safety

Chemical safety hazards are addressed in specific standards for the general and construction industries. This section highlights OSHA standards and other federal standards related to chemical hazards.

GENERAL INDUSTRY (29 CFR 1910)

- 1910 Subpart H, Hazardous Materials
 - 1910.106, Flammable and combustible liquids
 - 1910.119, Process safety management of highly hazardous chemicals
 - Appendix A, List of highly hazardous chemicals, toxins, and reactives
 - Appendix B, Block flow diagram and simplified process flow diagram
 - Appendix C, Compliance guidelines and recommendations for process safety management
 - Appendix D, sources of further information
- 1910 Subpart I, Fire protection
 - 1910.156, Fire brigades
- 1910 Subpart Z, Toxic and hazardous substances
 - 1910.1200, Hazard communication
 - 1910.1450, Occupational exposure to hazardous chemicals in laboratories

CONSTRUCTION INDUSTRY (29 CFR 1926)

- 1926 Subpart D, Occupational health and environmental controls
 - 1926.59, Hazard communication
 - 1926.64, Process safety management of highly hazardous chemicals
 - Appendix A, B, and C

OTHER FEDERAL STANDARDS*Department of Transportation (DOT)*

- 49 CFR 100–185, Subtitle B—Other regulations relating to transportation
 - Research and special programs administration (includes a Segregation Table for Hazardous Materials under section 177.848)

Environmental Protection Agency (EPA)

- 40 CFR 68, Protection of the environment: chemical accident prevention provisions. Includes a list of regulated substances and thresholds, the petition process for adding or deleting substances to/from the list of regulated substances, the requirements for owners or operators of stationary sources concerning the prevention of accidental releases, and approved state accidental release prevention programs.

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CHAPTER 2

Safety Is a Four-Letter Word

Fear is a survival function. You need it to survive. Hunting season in Maine when you're out and not dressed in red or orange. Fear makes you take note. Walking down the white line in the middle of the road. Fear tells you not to do it. I'm afraid of everything—elevators, cars.

—Stephen King (*Virginian-Pilot* 2007)

In late 1998, I (Frank R. Spellman) was invited by Dr. Greg Boardman, distinguished professor of civil engineering at Virginia Tech, to a meeting to be held in his Blacksburg, Virginia, campus office to discuss a forthcoming Virginia Tech-sponsored series of televised short courses dealing with worker on-the-job safety and organizational safety compliance. Dr. Boardman was well aware of my views on safety and safety compliance—he's attended several of my safety presentations (primarily for water/wastewater operators) at Virginia Tech during the 1994–1998 timeframe. He also knew that my views on safety and safety compliance were diametrically opposed to those of his good friend and colleague, Dr. E. Scott Geller, alumni distinguished professor at Virginia Tech and director of the Center for Applied Behavior Systems in the Department of Psychology. Dr. Geller is known (arguably) as the father of behavior-based safety (BBS). A well-respected, prolific writer and public speaker, Dr. Geller is a caring, dedicated, talented, and energetic professional. He is an interesting behavioral scientist, and fun to listen to. However, his views on safety and safety compliance (as Professor Boardman amply pointed out) are diametrically opposed to my own.

Dr. Geller and I entered Dr. Boardman's office and were seated in front of a large teleconference screen. We'd be joined remotely by a couple of other Virginia Tech psychology professors who were in northern Virginia on assignment, part of the group producing the proposed televised safety and safety compliance short course agenda.

While waiting for our teleconference to begin, Dr. Geller gave Dr. Boardman and me an explanation of his views on workplace safety. In particular, Dr. Geller explained a few behavior-based safety (BBS) principles and practices. He told us that BBS is the application of the science of behavioral change to real world problems. BBS “focuses on what people do, analyzes why they do it, and then applies a research-supported intervention strategy to improve what people do. . . . It has been proven that behavior influences attitude and attitude influences behavior” (Geller 1998).

Needless to say, I was fascinated by Dr. Geller’s brief explanation of BBS. Unfortunately, I did not have time to argue with him, to rebut him, and to explain to him why I thought his theory was incorrect. The professors joining us for the teleconference broke in. One of the long-distance professors who had been listening to Dr. Geller’s presentation greeted us, then basically said that in his opinion, Geller was wrong about BBS and its effect on workplace safety and safety compliance. The long-distance speaker (to this day I have not been able to pin down his name) said that “Safety and safety compliance can be summed up by a four-letter word: Fear.”

Finally, someone who shared my point of view (along with Stephen King) on safety and safety compliance! It is all about fear. As King said: “Fear is a survival function.” Safety and safety compliance are all about survival, our survival—it’s all about fear. We will discuss this fear element and its consequences in greater detail later.

Historical Perspective on Modern Safety and Safety Compliance

The modern safety movement is based primarily on American industrial safety pioneer Herbert William Heinrich’s classic text, *Industrial Accident Prevention: A Scientific Approach* (1931; see Hayhurst 1932). Many current safety professionals believe that Heinrich’s work is the basis for behavior-based safety (BBS). Heinrich’s view on workplace accidents is that 95 percent of them are the result of unsafe acts by workers. He based this view on the written accident reports he reviewed completed by supervisors, who generally blamed workers for causing accidents.

One of Heinrich’s most-cited conclusions is that 88 percent of all workplace accidents and injuries/illnesses are caused by “man-failure.” Many have used this statement to justify the BBS theory. The reality is, however, that Heinrich actually encouraged employers to control hazards and not merely focus on workers’ behavior. Moreover, in his text, he devoted more than a hundred pages to the subject of machine guarding (classic examples of physical hazards). To emphasize his view of the importance of guarding against physical hazards, Heinrich wrote, “No matter how strongly the statistical records emphasize personal faults or how imperatively the need for educational activity is shown, no safety procedure is complete or satisfactory that does not provide for the . . . correction or elimination of . . . physical hazards” (Grimaldi and Simonds 1973).

In our view, Heinrich's principal contribution to the safety profession was his contention that science and engineering may be applied practically and successfully to the prevention of accidents. He used the term "science" in the sense of knowledge of principles or facts. He stressed the four fundamental principles of accident prevention as: (1) upper management interest and support (critical to the success of any safety program); (2) cause analysis (methods aimed at identifying the root cause of accidents); (3) selection and application of remedy (mitigation); (4) and executive enforcement of corrective practices (Hayhurst 1932).

Contemporary Behavior-Based Safety

Behavior-based Safety (BBS) is not new. BBS (much like Heinrich's view) assumes that the majority of injuries and illnesses are the result of unsafe acts by workers. We support this view to a point (it is difficult to argue against those who point out that workers commit unsafe acts), and so do many large companies such as DuPont and Behavior Science Technology (BST), who claim that between 80 percent and 95 percent of all accidents are caused by unsafe behavior. The problem arises, however, when one takes a closer look at everything Heinrich wrote in his classic text. For example, he raised the ugly twin heads of racism and bias when he pointed out that "ancestry and social environment are factors in every accident." Clearly, this convoluted statement is without merit.

Many practicing safety professionals feel that today's BBS programs are basically nothing more than Heinrich's erroneous, biased, and outdated theories repackaged as a gimmick for modern marketing. BBS takes the view that problematic employee behavior is the cause of occupational injuries and illnesses.

Many companies jump on the BBS bandwagon because they see it as their "silver bullet" to safety compliance; it makes safety compliance seem simple. Upper management often looks for gimmicks that will not interfere with present management structures (and therefore power structures—Machiavellian principles are still alive and well) and that are relatively cheap to install. For example, in most cases it is less expensive to install a BBS program than it is to reengineer (remove the hazards) for safety an entire plant, process, or machine. BBS also allows the manager to point the finger of blame for on-the-job-injuries to the worker, thus shifting any blame away from managers. In short, managers often look at BBS implementation as being the lesser of two evils—as the easy, "safer" way out.

Fast-Forward to the Present

In order to devise a safety culture and program that will actually work to protect chemical workers, we first must determine where the injuries and illnesses come from. Chemical hazards include any aspect of technology or activity that produces risk. The level of risk is primarily the combination of two factors: the level of toxicity present and the degree of exposure. The level of toxicity is reduced by substitution of materials and design. Exposure is most effectively reduced through the use of engineering controls such as safety devices, enclosures, guards, and ventilation systems.

A classic example of substitution for safety can be seen in the recent trend in the wastewater treatment industry to substitute less hazardous sodium hypochlorite for deadly chlorine gas in the disinfection process. While the use of sodium hypochlorite is more expensive than chlorine gas, because sodium hypochlorite is not an EPA/OSHA-listed hazardous material, extremely costly and cumbersome regulations on the use of chlorine are avoided. Moreover, as one wastewater treatment sanitation district general manager told us, “By using harmless sodium hypochlorite instead of deadly chlorine I am able to sleep better at night . . . because the liability issue is removed.” The liability issue referred to here is based on the possibility of deadly chlorine not only causing serious injury or worse to workers but also injury or damage to those beyond the plant/facility fenceline.

Hierarchy of Controls

Currently, professional safety practitioners who are not using BBS programs or who are using BBS but have found it inadequate for their needs are using or switching to other methodologies. One of the common approaches used today to incorporate safety into the chemical industry workplace is to employ effective control measures. These control measures have been a longstanding OSHA policy; OSHA calls them the “hierarchy of controls.” The hierarchy has also been an established industrial hygiene practice since the 1950s.

Widely accepted by health and safety practitioners, the hierarchy of controls establishes an order of preference for the selection of controls to minimize the risk associated with any hazard. As shown in table 2.1, the hierarchy of controls recognizes that design, elimination, and engineering controls are more effective in reducing risk than

Table 2.1. Hierarchy of Controls (most effective to least effective)

Elimination or Substitution

Eliminate hazardous materials or substitute safe materials for hazardous ones



Engineering Controls

Machine guarding/ventilation/enclosures



Warnings

Alarms/labels



Training and Administrative Controls

Safe work practices/training



Personal Protective Equipment (PPE)

Safety shoes, glasses, belts, ear plugs, hardhats, gloves

lower-level controls such as warnings, training, safe work practices, and personal protective equipment.

Found in almost every recognized and respected manual on health and safety, the point made by the hierarchy of controls (table 2.1) is that the highest-level feasible control should be used to control every chemical hazard.

It is interesting to note that we have never found the hierarchy of controls referred to anywhere in BBS literature.

BBS Inverts the Hierarchy

Instead of beginning with the chemical hazard, BBS programs begin with the identification of critical worker behaviors (wearing PPE and following safe work practices when working with or around chemicals). Remember that these methods of control are at the bottom of the hierarchy. This points to the obvious: BBS programs turn the hierarchy upside down.

From the discussion above, one does not need to be a student of rocket science to recognize and understand that there is a substantial difference between the hierarchy-of-control approach and the BBS approach. The hierarchy, in reducing risk, takes an objective and unbiased view of the chemical workplace by identifying hazards.

Safety Is a Survival Function

At this point in the discussion the reader might be confused. The confusion may stem from trying to determine if a behavior-based safety program or the hierarchy of control is the better program to implement to protect chemical workers on the job. Or the reader may be wondering if there is some other program available that is better than these to protect chemical workers. Simply, which program is best? Which should we implement? Others may feel the choice is obvious because we have stated (in our opinion) that the hierarchy of control is more effective than BBS. We have stated that the hierarchy-of-control procedure emphasizes eliminating the hazard over worker-behavior modification; thus, it is the best program, in our opinion.

It is normal and routine for workers to want to be safe on the job. No normal worker leaves home for the workplace with the thought of leaving their fingers, eyesight, scalp, or life at work. Being safe anywhere (including in the workplace) has everything to do with our natural, normal, healthy human desire to survive. And, as pointed out earlier, fear is a survival function.

Let's take a closer look at this fear as a survival function.

In the workplace, there are two kinds of fear: functional fear and dysfunctional fear. In using a Dr. Jekyll and Mr. Hyde analogy to make an obvious good vs. bad comparison, functional fear is good (Dr. Jekyll) and dysfunctional fear is bad (Mr. Hyde).

Functional fear is that fear that drives us to:

- obey the speed limit while driving our cars on the highway
- buckle up our seat belts before driving a car or riding in one
- avoid coming into contact with live electrical wires or connections
- lock the doors at night
- turn on the security alarm when leaving the house
- turn off the stove before leaving the house
- wear safety glasses to protect the eyes
- wear a face shield to protect the face
- avoid entry into a permit-required confined space without proper procedures
- wear safety shoes while operating a jack hammer
- pour acid into water and not water into acid
- never touch an unmarked container
- wear a gas mask when working with volatile substances
- never store Perchloric and organics side by side
- never dispose hot acid
- not touch anything that is not ours
- mark properly and double-bag or contain all chemical waste
- dispose properly of all chemical waste
- wear proper chemical-resistant gloves when handling chemicals

Dysfunctional fear drives us to:

- not report workplace safety hazards
- not report near-miss accidents in the workplace
- keep quiet when we should speak up
- not report on-the-job injuries
- be fearful all the time at work
- be anxious
- take our workplace problems home with us
- worry all the time
- see something evil behind every company move
- hate our supervisors
- hate our coworkers
- hate us
- loathe going to work
- feel ill most of the time
- not answer the phone
- be a hyperanxious animal
- be in a constant state of vigilance
- invent reasons for anxiety when there are none

Fear should be accepted as a survival function that only arises during danger and is very short in duration; overall, fear should be beneficial to our well-being.

So what does all this talk about fear have to do with making chemical industry workers safer on the job? Where does fear fit into the chemical-safety equation? The chemical-safety equation is shown below; keep in mind that the “fear” part of the equation is functional fear. Dysfunctional fear has no place in chemical safety, in chemical-safety compliance efforts, or anywhere else, for that matter.

$$\text{Leadership} + \text{Knowledge} + \text{Common Sense} + \text{Functional Fear} \\ = \text{Chemical Safety}$$

Let’s break this chemical-safety equation into its components so that we can better understand the positive synergy generated by the whole (the whole is greater than the sum of the parts).

1. **Leadership:** No safety program can succeed without upper management commitment and strong, effective leadership at the highest level. While it is critical to have the absolute support of the top manager in the organization to generate a strong organizational safety culture, it is important to point out that safety leadership must be exhibited at all levels of the organization. It does little good to have some managers on board the safety bandwagon while other managers pay it lip service only or give it no support at all.
2. **Knowledge:** In order for chemical workers to avoid hazards, they must know about the hazards they are or can be exposed to. For example, if they work with Perchloric acid, they need to know that it is a corrosive, an oxidizer, and a reactive chemical. If they work with benzene they need to know that it is an irritant as well as a flammable, toxic, and carcinogenic chemical. Chemical workers need to know their workplace and all chemicals they work with. This is not to say they must be well-trained chemists, but at the minimum they must be well-trained on all existing and potential hazards. No chemical worker should be put to work without first undergoing a thorough orientation program focusing on all workplace hazards. Knowledge can be summed up with one word: training, training, training! Training is ongoing, never-ending, and critical to the knowledge component of the chemical-safety equation.
3. **Common sense:** Consider the following. After accepting the safety manager’s position, the newly hired safety professional sat in the general manager’s office receiving a welcome-aboard greeting from the general manager (GM). During the welcoming, the general manager stated that he was not sure what the new safety manager would be doing. “Maybe you’ll be teaching safety in our apprenticeship program . . . guess we will find something for you to do,” he said. Later, the GM added, “You know, in my opinion . . . safety is relative.” The new safety manager, who was somewhat mesmerized, stunned by the GM’s comments, wanted to ask one question: “Safety is relative? Relative to what?” However, having been on the job for less than an hour, the new safety manager said nothing. But she clearly understood that she had her work cut out for her—that is, if after digesting her welcome aboard, she were to decide to stay with the organization.

The incident just described actually occurred and it still amazes us that anyone in a position of authority and power who is responsible for the safety and health of 600-plus employees could be so lacking in common sense. It was Voltaire who said that common sense is not so common. Based on our over 30 years in the safety profession, we have found this statement to be true and maybe even a mild understatement. Has common sense gone the way of the dinosaur and dodo bird? We certainly hope not, but sometimes are left to wonder. Unfortunately, common sense can't be taught—you either have it or you do not. Thus, in any chemical industry organization, you have to ensure that only employees who have demonstrated good common sense are assigned highly dangerous work with chemicals and/or other processes.

4. **Functional fear:** When a chemical worker worries about hurting himself or herself, about hurting a coworker, about spilling a hazardous chemical and contaminating the environment, and/or about losing his or her job because of some unsafe act, the worry usually manifests itself in the exercise of caution. That is, the worker is careful, wary, restrained, and tentative about doing anything that will cause harm—to anyone. The point is that it is functional (good) fear that spawns these cautionary actions.

As stated above, when we add up all the ingredients in the chemical-safety equation we get chemical safety. Along with this beneficial result there is another important point to consider. One of the biggest headaches for any chemical industry manager is dealing with the regulators. Battling six-hundred-pound gorillas is never fun, but with regulators it can be a nerve-bender for sure. Like the criminal who commits a serious crime, who jumps every time the phone or doorbell rings, the chemical industry owner or manager who is not in compliance with OSHA, EPA, and local codes has got to feel (unless totally ignorant) the same sense of fear that the criminal does. One thing we know for certain, when in compliance with regulatory requirements, there is no fear. There is a spiritual saying that is apropos here:

Fear knocked at the door.
Faith answered.
No one was there.

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CHAPTER 3

The Chemical Industry

From October 2004 until September 2005, OSHA issued 1,740 citations to the chemical industry and fines totaling \$1,700,000. The average worker incidence rate was 3.5 per 100 full-time employees, and the chemical industry had 31 fatalities

—DOL (2008)

The U.S. chemical industry is vital to the U.S. economy. It is a high-tech, research-and-development (R&D)-oriented industry that is awarded about one out of every eight U.S. patents. Chemicals are an essential component of manufacturing in such fields as construction, motor vehicles, paper, electronics, transportation, agriculture, and pharmaceuticals. Although some chemical manufacturers produce and sell consumer products such as bleach, cosmetics, and soap, most chemical products are used as intermediate products for other goods. The chemical industry produces 1.9 percent of U.S. gross domestic product (GDP). It is the nation's number one exporter (USDC 1996; BLS 2008). The U.S. Department of Commerce lists chemicals as a “keystone” industry—one critical to the global competitiveness of other U.S. industries (USDC 1996).

Did You Know?

The U.S. chemical industry employs more than one million people and it produces over 70,000 products.

Major Components of the U.S. Chemical Industry

Because of the many different products and processes of the chemical industry it is difficult to create a meaningful description of the industry. However, essentially at the base of the chemical industry are companies that combine organic and inorganic

materials from the earth with heat, air, and water to make chemicals that, in turn, are essential to products used in everyday life in modern economies. The following sidebar outlines the major components of the industry.

Major Components of the U.S. Chemical Industry

The U.S. chemicals and allied products industry consists of some 9,125 corporations whose primary business is the development, manufacturing, and marketing of industrial chemicals, pharmaceuticals, and other chemical products.

The industrial chemicals segment (SICs 281, 282, and 286) of the industry consists of some 1,725 corporations whose primary business is the manufacturing and marketing of alkalis and chlorine, inorganic pigments, industrial gases, and other industrial inorganic chemicals; plastic resins, synthetic rubber, and man-made fibers; and petrochemicals and other industrial organic chemicals.

The pharmaceuticals segment (SIC 283) consists of some 1,225 corporations whose primary business is the development, manufacturing, and marketing of medicinal chemicals and botanicals; in vitro and other substances to diagnose or monitor the state of human or veterinary health; bacterial and virus vaccines, toxoids, serums, plasmas, and other biological products for human and veterinary health; and vitamins and other pharmaceutical preparations for both human and veterinary use.

Other chemical products (SICs 284, 285, 287, and 289) consist of some 6,175 corporations whose primary business is the manufacturing and marketing of soaps and detergents; surfactants; specialty cleaning, polishing, and sanitary preparations; perfumes, cosmetics, and other toilet preparations; paints, varnishes, enamels, and other allied products; fertilizers, pesticides, and other agricultural chemicals; and adhesives and sealants, explosives, printing ink, and other specialty chemicals and chemical preparations (USDC 1996).

Occupations in the Industry

According to the Bureau of Labor Statistics, in 2008, about 54 percent of those employed in the industry worked in production and in installation, maintenance, and repair occupations. Another 12 percent worked in professional and related occupations. Approximately 20 percent worked in management, business, and financial occupations and in office and administrative support occupations, and another 9 percent worked in transporting and material moving occupations.

Production occupations. Workers in production occupations operate and fix plant machinery, transport raw materials, and monitor the production process. Production workers include:

- Chemical plant and system operators
- Industrial machinery mechanics and machinery maintenance workers
- Inspectors, testers, sorters, samplers, and weighers
- Packaging and filling machine operators and tenders
- Transportation and material moving workers

Professional and related occupations. Most workers in professional and related occupations have at least a college degree, and many have advanced degrees. Professional workers include:

- Chemists and materials scientists
- Chemical engineers
- Engineering and science technicians

Management, business, and financial occupations. Most managers need a 4-year college degree in addition to experience in the industry. As in other highly technical industries, top managerial positions often are held by those with substantial technical experience. Management, business, and financial occupations include:

- Engineering managers
- Marketing and sales managers

Office and administrative support occupations. Office and administrative support workers perform office functions such as secretarial duties, bookkeeping, and material records processing, among others (BLS 2008).

Work Environment

The chemical industry is one of the nation's most regulated industries. It is subject to numerous environmental regulations as well as the voluntary obligations imposed by the chemical industry's environmental, health, and safety improvement initiatives. Including federal/state OSHA statutes, sixteen major federal statutes, as well as numerous state laws, impose significant compliance and reporting requirements on the industry (see sidebar).

Major Health, Safety, and Environmental Legislation

1. **Toxic Substances Control Act (TSCA) of 1976** gives the Environmental Protection Agency (EPA) comprehensive authority to regulate any chemical substance whose manufacture, processing, distribution in commerce, use, or disposal may present an unreasonable risk of injury to health or the environment.
2. **Clean Air Act (CAA)** was first passed in 1955 as the Air Pollution Control, Research and Technical Assistance Act and amended in 1963 to become the CAA. A more significant statute was passed in 1970 and amended in 1977 and 1990. It provides EPA authority to regulate air pollutants from a wide variety of sources including automobiles, electric power plants, chemical plants, and other industrial sources.
3. **Clean Water Act (CWA)** was first enacted in 1948 as the Federal Water Pollution Control Act. Subsequent extensive amendments defined the statute to be known as the CWA in 1972; it was further amended in 1977 and 1987. The CWA provides EPA authority to regulate effluents from sewage treatment works, chemical plants, and other industry sources into U.S. waterways. EPA has recently undertaken control efforts in non-point source pollution as well.
4. **Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA)** provide the basic legal framework for the Federal "Superfund" program to clean up abandoned hazardous waste sites.
5. **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** provides EPA authority to register and assess the risks of agricultural pesticides. It was first enacted in 1947 and last amended in 1988.
6. **Federal Food, Drug and Cosmetics Act (FDCA)** provides the Food and Drug Administration (FDA) authority to regulate the manufacturing of drugs and pharmaceuticals and the use of packaging and additives in food and cosmetics.
7. **Emergency Planning and Community Right-to-Know Act of 1986**, also known as SARA Title III, mandates state and community development of emergency preparedness plans and also establishes an annual manufacturing-sector emissions reporting program.
8. **Resource Conservation and Recovery Act (RCRA) of 1976** provides EPA with authority to establish standards and regulations for handling and disposing of solid and hazardous wastes.
9. **Occupational Safety and Health Act (OSH Act) of 1970** provides the Department of Labor authority to set comprehensive workplace safety and health standards, including permissible exposures to chemicals in the workplace, and authority to conduct inspections and issue citations for violations of safety and health regulations.

10. **Safe Drinking Water Act**, enacted in 1974 and amended in 1977 and again in 1986, establishes standards for public drinking water supplies.
11. **Hazardous Materials Transportation Act (HMTA)** provides the Department of Transportation the authority to regulate the packaging and movement of hazardous materials.
12. **Chemical Diversion and Trafficking Act (CDTA) of 1988** is designed to prevent the diversion of chemicals to illegal drug producers.
13. **Pollution Prevention of Act of 1990** makes it the national policy of the United States to reduce or eliminate the generation of waste at the source whenever feasible and directs the EPA to undertake a multimedia program of information collection, technology transfer, and financial assistance to the states to implement this policy and to promote the use of source reduction techniques.
14. **Flammable Fabrics Act**, enacted in 1970 and last amended in 1983, gives the Consumer Product Safety Commission the authority to set flammability standards for fabrics that protect against an unreasonable risk of the occurrence of a fire.
15. **Poison Packaging Prevention Act of 1953**, and last amended in 1990, provides the Consumer Product Safety Commission authority to set standards for the special packaging of any household product to protect children from a hazard.
16. **Consumer Product Safety Act**, enabled in 1972, created the Consumer Product Safety Commission and gives the Commission authority to issue mandatory safety standards, ban hazardous products, investigate safety of products, and use other forms of corrective action.
17. **State Regulations**. State governments are increasingly active in the environmental and safety areas. (USDC 1996).

Did You Know?

The costs of meeting mandated and self-imposed environmental requirements are large and continue to grow. Indeed, about one-sixth of new P&E investment is for environmental improvement purposes rather than to improve productivity or increase output.

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CHAPTER 4

Learning from the Past

Chemicals are ubiquitous in industrial operations. Given their wide application, it is not surprising that chemical incidents or exposures continue at a rate of approximately one a day.

All chemical exposures have the potential for health consequences. Depending on the toxicology and concentration, the effects of chemical exposures may be immediate (acid burns) or long term (chronic beryllium disease or cancer). In any case, chemical exposures may result in life-threatening outcomes. Chemicals may cause physical damage such as explosions or fires resulting in serious injury and facility damage. Facility and mission related effects might include corrosive actions that degrade equipment performance and residual contamination that limits the future use of facilities and equipment. Environmental issues may arise as a result of spills, releases, or waste chemical inventories. In addition to the health effects, physical damage, or environmental effects that may result from a chemical incident, there will be a need to apply scarce resources to incident mitigation.

—U.S. Department of Energy (2004)

The seasoned safety professional comes to believe in the age-old words of wisdom that if we do not learn from the past then we are doomed to repeat it. Understanding the past helps one understand the present—in regard to worker safety and health, this also applies to foretelling potential events in the future. This is especially true if chemical accident near-misses or close calls are not reported. Experience has shown that workers are reluctant to report them.

Actual chemical-related industrial catastrophic events, however, are quite public and tragic. Cases such as these are investigated by EPA and/or OSHA. Many of these cases involved fatalities. All involved worker injuries and substantial on-site property damage. Many had some significant impact on people in nearby residential communities. The underlying purpose of these investigations is always to determine causal factors. In such cases, the investigative findings result in the affected facility being required to implement proper mitigation procedures to prevent recurrence.

Again, the best way to learn is through experience. Thus, in this chapter we present the following representative list of some of the more notable among chemical industry incidents that resulted in on-site or off-site damage and fatalities, along with contamination of the environment (see sidebar). Some of these were joint EPA/OSHA investigations, while others were investigated by EPA alone (OSHA investigated all of these accidents for violation of occupational health and safety laws. However, OSHA did not participate with EPA in a more in-depth “root cause” investigation for some of the incidents). Note: The following incident descriptions are from EPA/OSHA archived expert review files as cited. (Many of the terms and requirements mentioned in the following apply to OSHA’s Process Safety Management (PSM) 29 CFR 1910.119 and EPA’s Risk Management Plan (RMP)—these are discussed in chapter 6.

Representative List of EPA/OSHA-Investigated Major Chemical Accidents

(1) TERRA INDUSTRIES, INC., PORT NEAL, IA, DECEMBER 13, 1994

Incident Description: Explosion of an ammonium nitrate unit; 4 employees were killed, 18 were hospitalized. 5,700 tons of anhydrous ammonia and 25,000 gallons of nitric acid were released. Residents were evacuated from the surrounding area, and ammonia plumes were detected several miles away.

Investigators’ Conclusion: The investigation team concluded that the explosion occurred as a direct result of a series of unsafe operating procedures and conditions at the Terra Port Neal complex. The team concluded that the conditions that caused the explosion existed primarily because of the lack of safe operating procedures at the plant. Most of the operating procedures that were used in the plant were not written (EPA 1996).

(2) POWELL DUFFRYN TERMINALS, INC. (PDTI), SAVANNAH, GA, APRIL 10, 1996

Incident Description: Crude sulfate turpentine fire and hydrogen sulfide release. The fire was probably ignited by a newly installed and improperly designed activated carbon vapor control unit. As a result 2,000 residents were evacuated for up to 30 days, an elementary school was temporarily closed, and nearby marsh water was contaminated.

Investigators’ Conclusion: This incident illustrates the failure of management systems to identify and evaluate the hazards associated with collocating incompatible materials inside single spill containment (EPA 1998a).

(3) NAPP TECHNOLOGIES, LODI, NJ, APRIL 21, 1995

Incident Description: A blender containing a mixture of sodium hydro-sulfite, aluminum powder, potassium carbonate, and benzaldehyde exploded, triggering a major fire. Water-reactive chemicals in the blender underwent an exothermic reaction after water contaminated the blender. Five fatalities and numerous injuries resulted. A nearby river was contaminated by runoff of firefighting water. A majority of the facility was destroyed as a result of the fire, and other businesses near the facility were destroyed or significantly damaged.

Investigators' Conclusion: Investigators identified the following root causes of and contributing factors to the event:

- An inadequate process hazards analysis (PHA) was conducted and appropriate preventive actions were not taken.
- Standard operating procedures and training were less than adequate.
- The decision to reenter the facility and off-load the blender was based on inadequate information.
- Communications between NAPP and a contributing operations company were inadequate.
- The training of fire brigade members and emergency responders was inadequate (EPA/OSHA 1997a).

(4) PENNZOIL PRODUCT COMPANY REFINERY, ROUSEVILLE, PA, OCTOBER 16, 1995

Incident Description: An explosion and fire erupted in storage tanks containing flammable hydrocarbons and wastewater. Hot work near the storage tanks probably ignited the explosion. Three employees were killed and three others were injured. Two later died as a result of their injuries. Employees at the plant and nearby offices, and residents from the town of Rouseville were evacuated.

Investigators' Conclusion: Investigators identified the following as root causes and contributing factors in the accident:

- Vessel design, integrity, and maintenance were inadequate.
- Preparation of hot work in the storage tank area was inadequate.
- There was a lack of awareness of the impact of changing conditions at the hot work site.
- Equipment siting and containment was inadequate (EPA 1998b).

(5) TOSCO COMPANY REFINERY, MARTINEZ, CA, JANUARY 21, 1997

Incident Description: A major fire started at a hydrocracker unit when a temperature excursion occurred, causing a piping elbow to

fail catastrophically. Four employees were killed and forty-four were injured. Nearby residents sheltered in place.

Investigators' Conclusion: Investigators identified the following as root causes and contributing factors in the accident:

- Tosco Avon refinery's maintenance management system did not recognize or control serious hazards posed by performing nonroutine repair work while the crude processing unit remained in operation.
- Tosco's safety management oversight system did not detect or correct serious deficiencies in the execution of maintenance and review of process changes at its Avon refinery.
- Tosco Avon refinery management did not conduct a Management of Change (MOC) review of operation changes that led to excessive corrosion rates in the naphtha piping.
- The crude unit corrosion control program was inadequate; they did not take timely corrective actions to prevent plugging and excessive corrosion in the piping (CSHIB 1999).

(6) SURPASS CHEMICAL COMPANY, ALBANY, NY, APRIL 8, 1997

Incident Description: A storage tank failed, causing a large spill of hydrochloric acid (HCl). The tank was overpressurized during a filling operation. A hydrochloric acid cloud drifted off-site, and spilled liquid entered the city storm sewer. 43 persons, including employees, were treated at hospitals; of these, 4 were hospitalized. One square block around the facility was evacuated. Students and faculty at nearby elementary schools sheltered in place.

Investigators' Conclusion: The investigation team determined that the immediate cause of the incident was the overpressurization of the HCl tank. The team identified the root causes as:

- Modifications to the venting of the HCl tank were not within the tank manufacturer's specifications for emergency venting.
- No hazard analysis of the modifications to the venting of the HCl tank was performed.
- Inadequate preventive maintenance of the scrubber system.
- Lack of a written standard operating procedure (SOP) for air off-loading of deliveries to the HCl tank, including an inadequate method for determining that the delivery was complete (EPA/OSHA 1997b).

(7) SHELL CHEMICAL COMPANY, DEER PARK, TX, JUNE 22, 1997

Incident Description: A large explosion and fire occurred in an olefins production unit. Shaft blow-out of a pneumatically assisted check

valve resulted in the release of large quantities of flammable hydrocarbon gas into a congested area. A vapor cloud explosion resulted, which was felt 10 miles away. Major plant damage occurred. One employee was hospitalized, and several others received minor injuries. Nearby residential areas suffered minor blast damage, and residents sheltered in place. Highways west and south of the plant were closed for three hours.

Investigators' Conclusion: The investigators identified the following root causes of the accident:

- The Clow Model GMZ check valves installed in the OP-III process gas compression system were not appropriately designed and manufactured for the heavy-duty service they were subject to in OP-III. This resulted in the valves being susceptible to shaft flow-out during normal use.
- Lessons learned from prior incidents involving Clow Model GMZ check valves installed at Shell facilities were not adequately identified, shared, and implemented. This prevented recondition and correction of the valve's design and manufacturing flaws at OP-III prior to the accident.
- The process hazards analysis (PHA) of the process gas compression system was inadequate; the PHA did not identify the risks associated with shaft blow-out in Clow Model GMZ check valves, and consequently no steps were taken to mitigate those risks.
- Measures necessary to maintain the mechanical integrity of Clow Model GMZ check valves installed in OP-III were not taken. This resulted in undetected damage to and eventual failure of critical internal valve components.
- Operating procedures for the start-up of the process gas compression (PGC) system did not specifically instruct operators to re-verify the position of pneumatically assisted check valves before restarting the compressor following unexpected automatic compressor trips; consequently, operators did not re-verify the position of the valve that failed. Re-verification might have enabled operators to observe possible indications of the fifth stage suction check valve's imminent failure on June 22, 1997.
- The lack of clear and immediate indications in the control room of a hydrocarbon leak contributed to the severity of the accident by significantly delaying operator action to shut down and depressurize the PGC system.
- Inadequate communications practices during the accident contributed to its severity by hindering the timely flow of information to control room operators (EPA/OSHA 1998).

(8) ACCRA PAC, ELKHART, IN, APRIL-NOVEMBER 1997

Incident Description: A series of explosions and fires involving ethylene oxide (ETO) packaging or sterilization operations occurred between

April and November 1997; two of the incidents occurred after installation of catalytic oxidizers in ETO exhaust ventilation systems. As a result of an accident one employee was killed, 59 others were treated at a hospital, and 3 were hospitalized. Approximately 2,500 people were evacuated from a 1-mile radius around the Accra Pac plant.

Investigators' Conclusion: The investigators found the following root causes of the accident:

- Inadequate shutdown procedure. When the breathing air supply to the respirator was interrupted, there was a hurried shutdown of the filling operation. The shutdown steps taken included blocking off the containers on the incoming conveyor and cutting the air supply used to drive the Graco pump. None of the valves in the ethylene oxide supply system were closed. In the event of a leak in the system within the Gas House, the pressurized ethylene oxide in the storage tanks located outside the Gas House could discharge into the Gas House.
- Location of the reclamation tank. Locating the reclamation tank, which holds up to 20 pounds of ethylene oxide, inside the Gas House violates good industry practice for minimizing the quantity of hazardous material in an occupied area. A leak in the reclamation tank system could result in a discharge that would exceed the Lower Explosive Limit (LEL). Also, the reclamation tank did not have instrumentation for monitoring the amount of liquid it contained. Overfilling the tank could lead to over-pressure, which in turn could lead to a rapid release of its contents.
- Lack of sufficient barriers or separation spacing between the Gas House and the Production Building. Per National Fire Protection Agency (NFPA) Code 30, 5-3.2.2, "Where Class IA liquids or unstable liquids, regardless of class, are handled or processed, the exposing walls shall have explosion resistance in accordance with good engineering practice." The Production Building did not provide sufficient explosion resistance to protect the occupants. The door on the Production Building was blown off its mounting. The employee in the Production Building was killed when struck by the door.
- Insufficient explosion venting to permit adequate pressure release. Pursuant to determinations using guidelines found in NFPA Code 68, a much larger vent area should have been provided to allow explosion pressure release without destruction of the building. The Gas House is designed with deflagration panels. The deflagration panels are to blow out to permit adequate pressure release in the event of an explosion inside the Gas House. The line No. 61 Gas House's deflagration panels were designed for use with members of the NEC Group D flammable vapors, of which propane is a member. The fundamental burning velocity and the rate of explosion pressure rise of ethylene oxide is over twice that of propane. The explosion vents of the Gas House were barely adequate for propane. The explosion vents were not adequate for ethylene oxide, which is much more hazardous than propane in terms of explosions.

- Inadequate door design. The doors on the Gas House were not permitted to swing open freely in response to the explosion. There was damage on the door jambs. The damage indicated that the doors were closed with the latches in the closed position. NFPA 68, 9-4.1 for venting of deflagrations states that hinged doors should swing outward and have latches that release under slight internal pressure. If the doors were less restrained and able to swing open easily, they could have swung open with the explosion and have been less likely to be blown off, thus reducing the likelihood of injuries and property damage. The doors opening easily would also limit the pressure buildup in the Gas House and reduce the explosion blast effect.
- Use of electrical equipment that did not meet National Electrical Code (NEC) requirements. Ethylene oxide is a NEC Class 1, Division 1, Group B material. The Gas House did not meet the NEC requirement for working with ethylene oxide. The electrical equipment in the Gas House could have predicted initiation for the explosion (EPA 2000).

(9) GEORGIA PACIFIC, COLUMBUS, OH, SEPTEMBER 10, 1997

Incident Description: An explosion occurred in the phenol/formaldehyde reaction kettle of a resin manufacturing process. Reactants were added to the kettle in the wrong sequence and at an excessive rate, resulting in an uncontrolled exothermic reaction. One employee was killed and 13 others were treated for injuries. Fifteen nearby homes were evacuated.

Investigators' Conclusion: The investigators found the following root causes of the accident:

- Process safety information did not include process chemistry for No-volak resin batches.
- Process safety information did not include all safe upper and lower limits.
- Process safety information did not include an evaluation of every consequence of deviation.
- Process safety information did not include accurate piping and instrument diagrams.
- K-2 process hazard analysis did not consider all the hazards of the process.
- K-2 process hazard analysis did not address the consequences of engineering control failure.
- Process hazard analyses did not address facility siting.
- Human factors checklists in the process hazard analyses were not completed.
- The employer did not communicate the actions of the K-2 process hazard analysis to all affected employees.

- The employer did not certify annually that the operating procedures were current and accurate.
 - Inspections and tests on process equipment did not address all items related to mechanical integrity.
 - All affected employees who operate resin batches were not informed of and trained in changes to the written operating procedures.
 - The incident investigation reports did not include factors which contributed to the incidents.
 - The incident investigation reports were not reviewed with all affected personnel.
 - The employer did not document that deficiencies found in the compliance audit were corrected.
 - Each affected employee did not wear a hard hat when working in areas where there was a potential for injury to the head from falling objects.
 - The resin reactor vessels and associated controls were not sufficient to minimize uncontrolled exothermic phenol-formaldehyde reactions.
 - The employer did not develop and implement written operating procedures that provided clear instructions for safely manufacturing resins.
 - The written operating procedures did not address all the requirements for the operating limits.
 - The written operating procedures did not effectively address the requirements for the safety and health considerations.
 - The training program for operators did not include all the required elements.
 - The employer did not provide refresher training to each operator.
 - The employer did not correct deficiencies in equipment that were outside acceptable limits before further use or in a safe and timely manner (OSHA 1998).
-

We Must Learn from Past Mistakes

Chemical incidents like those described here are more common than you might think. It is not uncommon to hear about a chemical spill or other type of chemical catastrophe on a weekly or monthly basis. In studying the historical record of chemical incidents, a few things seem certain. For instance, safety in the chemical industry can only be achieved by identifying hazards, performing risk assessment, and implementing accident prevention procedures. Sounds simple enough. So the question becomes: if we know how to prevent such incidents from occurring in the first place, why is it that they still occur?

Another item seems certain to us: based on our more than three decades of personal experience in investigating chemical incidents, because of lack of communication

at all levels, these types of incidents are bound to continue. We simply have not learned (and do not learn) from previous mistakes. Maybe the problem is lack of communication and/or lack of knowledge. Maybe the problem comes down to a lack of functional leadership. Experience has shown that many chemical disasters are caused by lack of leadership or presence of dysfunctional leadership.

The term *dysfunctional leadership* is easy to write but not always easy to define. Based on our experience, dysfunctional leadership is manifested any time the following organizational roadblocks are apparent:

- poor communication
- low trust
- low credibility—managers don't walk the walk
- lack of consistency
- blame
- misuse of downstream measures
- no buy-in
- no team play
- company culture does not value safety
- production pressures
- safety and health program lacks clear purpose and direction
- there are no clearly defined roles and responsibilities for safety at all levels
- dysfunctional fear
- peer pressure
- lack of integration with other processes
- lack of top management commitment and involvement

References and Recommended Reading

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CHAPTER 5

Chemical Safety and Hazard Communication

The Bhopal incident, the ensuing chemical spill, and the resulting tragic deaths and injuries are well known (see the prologue). However, not all of the repercussions—the lessons learned—from this incident are as well known. After Bhopal arose a worldwide outcry. “How could such an incident occur? Why wasn’t something done to protect the inhabitants? Weren’t there safety measures taken or in place to prevent such a disaster from occurring?”

In the United States, these questions and others were bandied around by the press and Congress, and Congress took the first major step to prevent such incidents from occurring in the United States. What Congress did was direct the Occupational Safety and Health Administration (OSHA) to take a close look at chemical manufacturing in the United States to see if a Bhopal-type incident could occur in this country. OSHA did a study, then reported to Congress that a Bhopal-type incident in the United States was very unlikely. Within a few months of OSHA’s report to Congress, however, a chemical spill occurred in Institute, West Virginia—similar to Bhopal, but fortunately, not deadly (no deaths, over 170 people became ill).

Needless to say, Congress was upset. Because of Bhopal and the Institute, West Virginia, fiasco, OSHA mandated its Hazard Communication Program, 29 CFR 1910.1200, in 1984. Later, other programs like the Superfund Amendments and Reauthorization Act (SARA) Title III reporting requirements for all chemical users, producers, suppliers, and storage entities, were mandated by the Environmental Protection Agency (EPA).

After Bhopal and Institute, West Virginia, Congress decided that those personnel involved with working with or around hazardous materials had a right to know about the hazards near them, or the ones they worked with. Thus, OSHA’s Hazard Communication Standard was created. The Hazard Communication Standard is, without a doubt, the regulation most important to the communication of hazards to employees.

Under its Hazard Communication Standard (more commonly known as “HazCom” or the “Right-to-Know Law”), OSHA requires employers who use or produce chemicals on the worksite to inform all employees of the hazards that might be involved with those chemicals. HazCom says that employees have the right to know

what chemicals they are handling, or could be exposed to. HazCom's intent is to make the workplace safer. Under the HazCom Standard, the employer is required to fully evaluate all chemicals on the worksite for possible physical and health hazards. All information relating to these hazards must be made available to the employees twenty-four hours each day. The standard is written in a performance manner, meaning that the specifics are left to the employer to develop.

The HazCom Standard doesn't provide any single all-inclusive list of chemicals it covers. However, the regulation refers to "any chemical which is a physical or health hazard." Those specifically deemed hazardous include:

- Chemicals regulated by OSHA in 29 CFR Part 1910, Subpart Z, Toxic and Hazardous Substances
- Chemicals included in the American Conference of Governmental Industrial Hygienists' (ACGIH) latest edition of *Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents in the Work Environment*
- Chemicals found to be suspected or confirmed carcinogens by the National Toxicology Program in the *Registry of Toxic Effects of Chemical Substances* published by NIOSH or appearing in the latest edition of the *Annual Report on Carcinogens*, or by the International Agency for Research on Cancer in the latest editions of its *IARC Monographs*

OSHA Standards Applicable to Hazard Communication

This section highlights OSHA standards related to hazard communication (HazCom).

GENERAL INDUSTRY (29 CFR 1910)

- 1910 Subpart Z, Toxic and hazardous substances
 - Appendix A, Health hazard definitions
 - Appendix B, Hazard determination
 - Appendix C, Information sources
 - Appendix D, Definition of "trade secret"
 - Appendix E, Guidelines for employer compliance
- 1910.1201, Retention of DOT markings, placards, and labels

SHIPYARD EMPLOYMENT (29 CFR 1915)

- 1915 Subpart Z, Toxic and hazardous substances
 - 1915.1200, Hazard communication

MARINE TERMINALS (29 CFR 1917)

- 1917 Subpart B, Marine terminal operations
 - 1917.28, Hazard communication
 - Appendix E, Guidelines for employer compliance

LONGSHORING (29 CFR 1918)

- 1918 Subpart I, General working conditions
 - 1918.90, Hazard communication

CONSTRUCTION INDUSTRY (29 CFR 1926)

- 1926 Subpart D, Occupational health and environmental controls
 - 1926.59, Hazard communication

**WORKPLACE HAZARD COMMUNICATION PROGRAM
(GENERAL—(e) (1))**

OSHA's Hazard Communication Standard requires that workplaces which must comply with the standard produce HazCom Programs in written form. In the February 9, 1994, Amendments to the Final Hazard Communication Rule, paragraph (e) (1) was modified slightly. New wording is indicated in *italics*:

- (1) Employers shall develop, implement and maintain *at each workplace*, a written hazard communication program describing how the requirements for labels, material safety data sheets, and employee information and training will be met.

WARNING LABELS

OSHA requires every manufacturer and importer of a chemical substance to ensure that each container of a hazardous substance is labeled, marked, and tagged with the identity of the product, appropriate hazard warnings, storage and handling information, and the name and address of the manufacturer, importer, or other responsible party. It is important to point out that HazCom also requires employers to ensure proper labeling (and/or notice) of each chemical hazard produced in the workplace, including chemicals that might be produced as off-gases. For example, in chemical production processes, two commonly produced off-gases are methane and hydrogen sulfide. These gaseous hazards can kill workers and/or do considerable physical damage

to the plant and equipment quickly, by exposing workers to either deadly inhalation hazards or explosion and fire.

ANSI Z535.4

Labels must be designed to be clearly understood by all workers. In order to ensure compliance with this requirement, the American National Standards Institute (ANSI) publishes the ANSI Z535 series of standards. According to ANSI Z535,

A product safety sign or label should alert persons to a specific hazard, the degree or level of hazard seriousness, the probable consequence of involvement with the hazard and how the hazard can be avoided.

ANSI Z535.4 (section 4) prescribes the use of signal words to communicate the degree of hazard seriousness. OSHA's 29 CFR 1910.145 sets the actual specifications for accident prevention signs and tags.

The ANSI Z535.4-2007 standard uses the following definitions for signal words (see figure 5.1):

- **4.14 *signal word*:** The word that calls attention to the safety sign and designates a degree or level of hazard seriousness. The signal words for product safety signs are “DANGER,” “WARNING,” “CAUTION,” and “NOTICE.”
- **4.14.1 DANGER:** Indicates a hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
- **4.14.2 WARNING:** Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **4.14.3 CAUTION:** Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **4.14.4 NOTICE:** “NOTICE” is the preferred signal word to address practices not related to personal injury.

NFPA 704-B AND HMIS LABELING SYSTEMS

In addition to signal words, pictures, symbols, or a combination of these will appear on labels or other forms of marking on containers to convey any health and/or physical hazards of the substance(s).

Two of the most common labeling systems are the National Fire Protection Association (NFPA 704-B; see figure 5.2) and the Hazardous Materials Identification System (HMIS). These systems provide a number key to indicate the relative hazard of the material in the areas of health, flammability, and reactivity. The number system is from “0” for nonhazards to “4” for extreme hazards.



[RED]



[ORANGE]



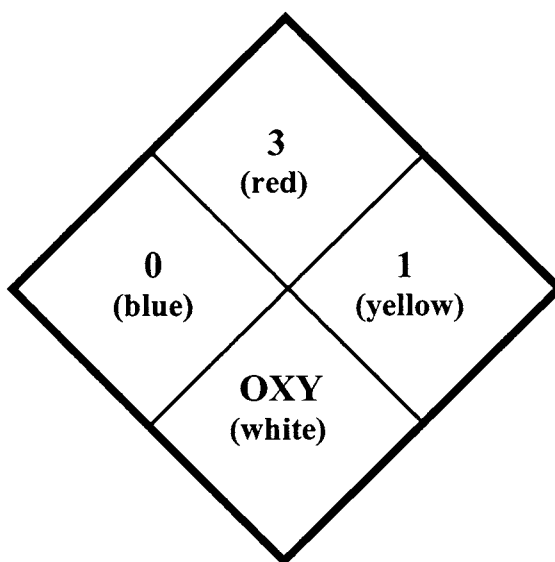
[YELLOW]



[BLUE]

Figure 5.1. ANSI signal words and signal word panels.

Figure 5.2. NFPA label.



The NFPA hazard warning (with labeling system numbers; see figure 5.2) was developed for short-term, often acute exposure to chemicals; it is diamond-shaped and displayed on a color-coded symbol or label as follows:

- **RED** (on top) background for **flammability** hazard
- **BLUE** (left corner) background for **health** hazard
- **YELLOW** (right corner) background for **reactivity (instability)** hazard
- **WHITE** (bottom) background for **special** hazardous properties of the material—e.g., poison, radioactive, corrosive, acid, oxidizer, water reactive, etc.

The HMIS system also includes a field for required personal protective equipment (PPE) to be used with the hazardous material.

On occasion, NFPA hazards are written horizontally, left to right, as NPFA “0–4” (health); “0–4” (flammability); “0–4” (reactivity/instability); “Special Hazards.”

TRAINING

In order for workers to comply with any organizational rule and/or OSHA standard (such as HazCom), they must be informed of the requirements. Employees must be trained in the hazards of, protective equipment for, and symptoms of overexposure to the material. Moreover, employees must be informed and advised of all hazards associated any time new hazardous materials are introduced into the workplace. This includes reviewing any new Material Safety Data sheet (MSDS) with employees before the new product is used. Simply, no product containing hazardous substances should be used until employees have been trained in its proper use, handling, and disposal;

employers are required to provide both training and written materials to make workers aware of what they are working with and what hazards they might be exposed to.

An important and often overlooked or ignored point regarding the training of employees can be summed up in one word: *DOCUMENT! DOCUMENT! DOCUMENT!* In the eyes of OSHA and a court of law, training that took place but was not properly documented is training that was *not* accomplished!

MATERIAL SAFETY DATA SHEET (MSDS)

An MSDS is a technical bulletin (fact sheet) containing detailed information about a hazardous substance. A manufacturer is required to prepare an MSDS for each hazardous substance it sells. OSHA requires manufacturers and distributors to provide a copy of the relevant MSDS when each sample or order of a hazardous substance is shipped by the manufacturer or other carrier to a location for the first time. Employers are required to make Material Safety Data Sheets (MSDSs) available to all employees. MSDSs must be in English, available 24/7, and contain the following information (Meyer 2005):

- Identity of the chemical (label name)
- Physical hazards
- Control measures
- Health hazards
- Whether it is a carcinogen
- Emergency and first aid procedures
- Firefighting measures
- Handling and storage information
- Exposure controls/PPE
- Stability and reactivity
- Toxicological properties
- Ecological information
- Regulatory information
- Transport information
- Date of preparation of latest revision
- Name, address, and telephone number of manufacturer, importer, or other responsible party
- Other information deemed important

Blank spaces are not permitted on an MSDS. If relevant information in any one of the categories is unavailable at the time of preparation, the MSDS must indicate no information was available. Your facility must have an MSDS for each hazardous chemical it uses. Copies must be made available to other companies working on your work-site (outside contractors, for example), and they must do the same for you. The facility Hazard Communication Program must be in writing, and along with MSDSs, made available to all workers twenty-four hours a day, seven days a week.

Material Safety Data Sheets (MSDSs)

The following information is required on an MSDS, which, as previously stated, must be in English.

1. Specific identity of each hazardous chemical or mixture ingredient and common product names
2. Physical and chemical characteristics of the hazardous material including:
 - a. Density or specific gravity of liquid or solid
 - b. Density of gas or vapor relative to air
 - c. Boiling point
 - d. Melting point
 - e. Flash point
 - f. Flammability range
 - g. Vapor pressure
3. Physical hazard data such as stability, reactivity, flammability, corrosivity, explosivity
4. Health hazard data including acute and chronic health effects, and target organ effects
5. Exposure limits such as OSHA Permissible Exposure Limits (PELs)
6. Carcinogenicity of material
7. Precautions to be taken, including use of PPE
8. Emergency and first aid procedures. This includes spill cleanup information and EPA spill reportability information
9. Supplier or manufacturer data including:
 - a. Name
 - b. Address
 - c. Telephone number
 - d. Date prepared
10. Miscellaneous information (local knowledge, phone numbers, points of contact, etc.)

An example of an MSDS is provided in the accompanying sidebar. It consists of several pages of information on the chemical product hydrogen peroxide. Note that it contains information relating to the categories listed above.

Did You Know?

Certain items do not require an MSDS:

- articles: pencils, pens, dishes, pots, pans, and so on
- food
- cosmetics

- drugs
- hazardous waste
- tobacco
- wood products
- consumer products
- nuisance dusts
- radiation
- biological hazards
- office and school supplies

MATERIAL SAFETY DATA SHEET

Hydrogen Peroxide (40 to 60%)

MSDS Ref. No. 6969-E
Version: US
Date approved: 02/29/08
Revision No: 7

XYZ INDUSTRIES

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: Hydrogen Peroxide (40 to 60%)

ALTERNATE TRADE NAME(S): Durox® 50% Reg. and LR 50%, Hybrite® 50%, Oxypure® 50%, Semiconductor Reg & Seg 50%, Standard 50%, Technical 50%, Chlorate Grade 50%, Super D® 50%

GENERAL USE: Durox® 50% Reg. and LR—meets the Food Chemical Codex requirements for aseptic packaging and other food-related applications.

Oxypure® 50%—certified by NSF to meet ANSI/NSF Std 60 requirements for drinking water treatment.

Standard 50%—most suitable for industrial bleaching, processing, pollution abatement, and general oxidation reactions.

Semiconductor Reg. & Seg. 50%—conforms to ACS and Semi Specs, for water etching and cleaning, and applications requiring low residues.

Super D® 50%—meets U.S. Pharmacopoeia specifications for 3% topical solutions when diluted with proper quality water. While manufactured to the USP standards of purity and to XYZ's demanding ISO 9002 quality standards, XYZ does not claim that its Hydrogen Peroxide is manufactured in accordance with all pharmaceutical cGMP conditions.

Technical 50%—essentially free of inorganic metals, suitable for chemical synthesis.

Chlorate Grade 50%—specially formulated for use in chlorate manufacture or processing.

MANUFACTURER

XYZ Industries
Hydrogen Peroxide Division
WW Granby Street
Norfolk, Va. 23503

General Information: (757) 588-766

XYZ Industries
Hydrogen Peroxide Division
6933 8th Ave NW
Seattle, WA 98107

Emergency Telephone Numbers:

CHEMTREC (U.S.): (800) 424-9300

Emergency Phone: (613) 999-6969

Emerg. Phone: (216) 776-9088

(Medical) Call Collect

Emerg. Phone: (761) 923-7745 (Plant)

General Information: (206) 123-3214 Call Collect

2. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Name	CAS#	Wt. %
Hydrogen Peroxide	7722-84-1	40–60
Water	7732-18-5	40–60

3. HAZARDS IDENTIFICATION**EMERGENCY OVERVIEW**

IMMEDIATE CONCERNS: Oxidizer. Contact with combustibles may cause fire. Decomposes yielding oxygen that supports combustion of organic matters and can cause overpressure if confined.

POTENTIAL HEALTH EFFECTS: Corrosive to eyes, skin, nose, throat, and lungs. May cause irreversible tissue damage to the eyes including blindness.

4. FIRST AID MEASURES

EYES: Immediately flush with water for at least 15 minutes, lifting the upper and lower eyelids intermittently. See a medical doctor or ophthalmologist immediately.

SKIN: Immediately flush with plenty of water while removing contaminated clothing and/or shoes, and thoroughly wash with soap and water. See a medical doctor immediately.

INGESTION: Rinse mouth with water. Dilute by giving 1 or 2 glasses of water. Do not induce vomiting. Never give anything by mouth to an unconscious person. See a medical doctor immediately.

INHALATION: Remove to fresh air. If breathing difficulty or discomfort occurs and persists, contact a medical doctor.

NOTES TO MEDICAL DOCTOR: Hydrogen peroxide at these concentrations is a strong oxidant. Direct contact with the eye is likely to cause corneal damage especially if not washed immediately. Careful ophthalmologic evaluation is recommended and the possibility of local corticosteroid therapy should be considered.

5. FIRE-FIGHTING MEASURES

FLASH POINT AND METHOD: Noncombustible

FLAMMABLE LIMITS: Noncombustible

AUTOIGNITION TEMPERATURE: Noncombustible

EXTINGUISHING MEDIA: Flood with water

FIRE/EXPLOSION HAZARDS: Product is noncombustible. On decomposition releases oxygen which may intensify fire.

FIRE-FIGHTING PROCEDURES: Any tank or container surrounded by fire should be flooded with water for cooling. Wear full protective clothing and self-contained breathing apparatus.

SENSITIVITY TO STATIC DISCHARGE: No data available

SENSITIVITY TO IMPACT: No data available

HAZARDOUS DECOMPOSITION PRODUCTS: Oxygen which supports combustion

6. ACCIDENTAL RELEASE MEASURES

RELEASE NOTES: Dilute with a large volume of water and hold in a pond or diked area until hydrogen peroxide decomposes. Hydrogen peroxide may be decomposed by adding sodium metabisulfate to sodium sulfite after diluting to about 5%. Dispose according to methods outlined for waste disposal.

Combustible materials exposed to hydrogen peroxide should be immediately submerged in or rinsed with large amounts of water to ensure that all hydrogen peroxide is removed. Residual hydrogen peroxide that is allowed to dry (upon evaporation hydrogen peroxide can concentrate) on organic materials such as paper, fabrics, cotton, leather, wood, or other combustibles can cause the material to ignite and result in a fire.

7. HANDLING AND STORAGE

HANDLING: Wear cup-type chemical safety goggles and full-face shield, impervious clothing, such as rubber, PVC, etc., and rubber or neoprene gloves and shoes. Avoid cotton, wool and leather. Avoid excessive heat and contamination. Contamination may cause decomposition and generation of oxygen gas, which could result in high pressures and possible container rupture. Hydrogen peroxide should be stored only in vented containers and transferred only in a prescribed manner. Never return unused hydrogen peroxide to original container; empty drums should be triple-rinsed with water before discarding. Utensils used for handling hydrogen peroxide should only be made of glass, stainless steel, aluminum, or plastic.

STORAGE: Store drums in cool areas out of direct sunlight and away from combustibles.

COMMENTS:

VENTILATION: Provide mechanical general and/or local exhaust ventilation to prevent release of vapor or mist into the work environment.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION**EXPOSURE LIMITS**

TWA	STEL/Ceiling	PEL	STEL/Ceiling
Chemical Name (ACGIH)	(ACGIH)	(OSHA)	(OSHA)
Hydrogen Peroxide		1 ppm	1 ppm

ENGINEERING CONTROLS: Ventilation should be provided to minimize the release of hydrogen peroxide vapors and mists into the work environment. Spills should be minimized or confined immediately to prevent release into the work area. Remove contaminated clothing immediately and wash before reuse.

PERSONAL PROTECTIVE EQUIPMENT

EYES AND FACE: Use cup-type chemical goggles. Full-face shield may be used.

RESPIRATORY: If concentrations in excess of 10 ppm are expected, use approved self-contained breathing apparatus. Do not use oxidizable sorbants such as activated carbon.

PROTECTIVE CLOTHING: Liquid-proof rubber or neoprene gloves. Rubber or neoprene footwear (avoid leather). ImperVIOUS clothing materials such as rubber, neoprene, nitrile, or polyvinyl chloride (avoid cotton, wool, and leather). Completely submerge hydrogen peroxide-contaminated clothing or other materials in water prior to drying. Residual hydrogen peroxide, if allowed to dry on materials such as paper, fabrics, cotton, leather, wood, or other combustibles can cause the material to ignite and result in a fire.

9. PHYSICAL AND CHEMICAL PROPERTIES

ODOR: Odorless

APPEARANCE: Clear, colorless liquid

pH: (as is) 1.0 to 3.0

PERCENT VOLATILE: 100%

VAPOR PRESSURE: 22 mmHg @ 30°C (40%); 18.3 mmHg @ 30°C (50%)

VAPOR DENSITY (Air = 1): Not available

BOILING POINT: 110°C (229°F) (40%); 114°C (237°F) (50%)

FREEZING POINT: -41.4°C (-42.5°F) (40%); -52°C (-62°F) (50%)

SOLUBILITY IN WATER: (in H₂O % by wt) 100%

EVAPORATION RATE (Butyl Acetate = 1): Above 1

DENSITY: Not available

SPECIFIC GRAVITY (H₂O = 1): 1.15 @ 20°C/4°C (40%); 1.19 @ 20°C/4°C (50%)

COEFF. OIL/WATER: Not available

ODOR THRESHOLD: Not available

OXIDIZING PROPERTIES: Strong oxidizer

COMMENTS: pH (1% solution): 5.0–6.0

10. STABILITY AND REACTIVITY

CONDITIONS TO AVOID: Excessive heat or contamination could cause product to become unstable.

STABILITY: Stable (heat and contamination could cause decomposition).

POLYMERIZATION: Will not occur.

HAZARDOUS DECOMPOSITION PRODUCTS: Oxygen which supports combustion.

INCOMPATIBLE MATERIALS: Reducing agents, wood, paper, and other combustibles, iron and other heavy metals, copper alloys, and caustic.

COMMENTS:

MATERIALS TO AVOID: Dirt, organics, cyanides, and combustibles such as wood, paper, oils, etc.

11. TOXICOLOGICAL INFORMATION

EYE EFFECTS: Severe irritant (corrosive), (rabbit), (70% hydrogen peroxide) (XYZ Study Number: ILK/S-69-069)

SKIN EFFECTS: Severe irritant (corrosive), (rabbit), (50% hydrogen peroxide) (XYZ Study Number: 169-6969)

DERMAL LD₅₀: > 6.5 g/kg (rabbit), (70% hydrogen peroxide) (XYZ Study Number: NNT/T-69.069)

ORAL LD₅₀: >225 mg/kg (rat), (50% hydrogen peroxide) (XYZ Study Number 69-9140)

INHALATION LC₅₀: >0.17 mg/L (rat), (50% \p \hydrogen peroxide) (XYZ Study Number 66-1230)

TARGET ORGANS: Eye, skin, nose, throat, lungs

ACUTE EFFECTS FROM OVEREXPOSURE: Severe irritant/corrosive to eyes, skin, and gastrointestinal tract. May cause irreversible tissue damage to the eyes including blindness; inhalation of mist or vapors may be severely irritating to nose, throat, and lungs.

CHRONIC EFFECTS FROM OVEREXPOSURE: There are reports of limited evidence of carcinogenicity of hydrogen peroxide to mice administered high concentrations in their drinking water (IARC Monograph 36, 1985). However, the International Agency For Research on Cancer concluded that hydrogen peroxide could not be classified as to its carcinogenicity to humans (Group III carcinogen).

CARCINOGENICITY

Chemical Name	NTP	IARC	OSHA	Other
	Status		Status	Status
Hydrogen Peroxide	Not listed	Not listed	Not listed	(ACGIH) Listed (A3, Animal Carcinogen)

12. ECOLOGICAL INFORMATION**ECOTOXICOLOGICAL INFORMATION:**

Channel catfish 96 hour LC50 = 37.4 mg/L
Fathead minnow 96 hour LC50 = 16.4 mg/L
Daphnia magna 24 hours EC50 = 7.7 mg/L
Daphnia pulex 48 hours LC50 = 2.4 mg/L
Freshwater snail 96 hour LC50 = 17.7 mg/L

CHEMICAL FATE INFORMATION: Hydrogen peroxide in the aquatic environment is subject to various reduction or oxidation processes and decomposes into water and oxygen. Hydrogen peroxide half-life in freshwater ranged from eight hours to twenty days, in air from ten to twenty hours, and in soils from minutes to hours, depending upon microbiological activity and metal contaminants.

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: An acceptable method of disposal is to dilute with a large amount of water and allow the hydrogen peroxide to decompose followed by discharge into a suitable treatment system in accordance with all regulatory agencies. The appropriate regulatory agencies should be contacted prior to disposal.

14. TRANSPORT INFORMATION

U.S. DEPARTMENT OF TRANSPORTATION (DOT)

PROPER SHIPPING NAME: Hydrogen peroxide, aqueous solutions with more than 40% but not more than 60% hydrogen peroxide.

PRIMARY HAZARD CLASS/DIVISION: 5.1 (Oxidizer)

UN/NA NUMBER: UN 2014

PACKING GROUP: II

PLACARD: 5.1 (Oxidizer)

LABEL: Oxidizer Corrosive

OTHER SHIPPING INFORMATION:

DOT Marking: Hydrogen Peroxide, aqueous solution with more than 40%, but not more than 60%

Hydrogen Peroxide, UN 2014

Hazardous Substance/RQ: Not applicable

49 STCC Number: 4918776

Aluminum tanks, drum/DOT 42D

SPECIAL SHIPPING NOTES: IMDG: Hydrogen Peroxide, aqueous solutions with more than 40%, but not more than 60% hydrogen peroxide.

IATA: Hydrogen peroxide (40–60%) is forbidden on Passenger and Cargo Aircraft, as well as Cargo-Only Aircraft.

Protect from physical damage. Keep drums in upright position. Drums should not be stacked in transit. Do not store drums on wooden pallets.

15. REGULATORY INFORMATION

UNITED STATES

SARA Title III (Superfund Amendments and Reauthorization Act)
SARA Title III Section 302 Extremely Hazardous Substances
(40 CFR 355):

Hydrogen Peroxide >52%
RQ: 1,000 lbs
Planning Threshold: 1,000 lbs.

Section 311 Hazard Category (40 CFR 370):

Fire Hazard
Immediate (Acute) Health Hazard

Section 312 Threshold Planning Quantity (40 CFR 370):

(Conc. >52%; 10,000 lbs. (conc. <52%))

Section 313 Reportable Ingredients (40 CFR 370):

Not listed

CERCLA (Comprehensive Environmental Response Compensation and Liability Act)

CERCLA Regulatory (40 CFR 302.4):

Unlisted (Hydrogen Peroxide):
RQ = 100 lbs.
Ignitability, Corrosivity

TSCA (Toxic Substance Control Act)

TSCA Status (40 CFR 710): Listed

RCRA Status: Waste No. D001 Waste No. D002

CANADA

WHMIS (Workplace Hazardous Materials Information System):

Hazard Classification Class C (Oxidizer), Class D, Div. 2 Subdiv.
B, Class E (Corrosive)
Product Identification No.: 2014
Ingredients Disclosure List: Listed

16. OTHER INFORMATION

REVISION SUMMARY

This MSDS replaced Revision #7, dated September 11, 2001.
Changes in information are as follows:

HMIS HEADINGS

HMIS RATING

Health	3
Flammability	0
Physical Hazard	1
Protection (PPE)	H

NFPA RATING

Health	3
Flammability	0
Reactivity	1
Special	OX

Key:

4 = Severe

3 = Serious

2 = Moderate

1 = Slight

0 = Minimal

HMIS RATINGS NOTES: Protection = H (safety goggles, gloves, apron; the use of a supplier air or SCBA respirator is required in lieu of a vapor cartridge respirator.)

GENERAL STATEMENTS: Note: NFPA—Reactivity is 3, when greater than 52%.

CHEMICAL INVENTORY

Experience has shown that when OSHA conducts a compliance audit of a plant, facility, and/or other workplace, the auditors routinely seek out and document any container containing hazardous materials. When they find one (and more), they usually write down the brand name of the product and later ask to see an MSDS for each product found. Again, based on personal experience, it is at this point in the audit process that the property owner or manager gets into trouble with OSHA compliance (if not already there). We have found that it is not unusual for the in-house facility compliance manager to forget the Hazard Communication Standard requirement for the facility to produce and maintain a current inventory of all chemical products within the workplace.

An initial inventory of all chemicals should be made of all new work areas and facilities. A routine audit, the HazCom Inventory, should be conducted thereafter. We have found that this should be done on a quarterly basis (during a regularly scheduled in-house audit, for example). Additionally, someone should be designated (for example, shipping and receiving personnel) to identify new chemicals and ensure they are accompanied by an MSDS. After identification and listing on the HazCom Inventory, employees who may come into contact with the new chemical must be notified and made aware of the product's potential hazards. A copy of the HazCom Inventory for each work area should be kept with the MSDS for that area and the updated inventory lists provided to the Environment, Health & Safety office.

Each listing should note at least the following information:

1. Name and contact information for persons responsible for the area or chemicals
2. Date the list was compiled or updated
3. Building and room/area location of the work or storage area
4. Name and hazard(s) of the chemical or product
5. Typical maximum quantity of the chemical or material
6. General location within the work area where material is kept

- 7 Name of the manufacturer or supplier (to prevent OSHA citation, this must match the MSDS)

Again, the importance of incorporating a system to add any newly introduced hazardous chemicals or materials to the inventory can't be overstressed. Typically, the person responsible for material will update the list for the specific work area and ensure that the master list is updated. The EH&S practitioner or responsible person for the area will ensure that the list is updated.

INFORMING CONTRACTORS

It is important to inform any person, including outside contractors and visitors, who might come into contact with on-site hazardous chemicals/materials (or who brings such products on the plant site) of the inherent hazards presented. It is the responsibility of the host facility to provide contractors and visitors with the following information:

1. Any hazardous chemicals to which they may be exposed while on the site.
2. Precautions and controls to be taken to lessen or prevent possible exposure by use of appropriate protective measures.
3. The EH&S practitioner is usually the designated person responsible for contacting each and all contractors/visitors before the work or visit is started to gather and disseminate any information concerning chemical hazards that the contractor may be bringing onto the worksite. Whenever any department official initiates a work or construction contract, he or she should notify the EH&S person of such contract, the name of the contractor, the starting date, and the type of work to be performed.

HAZCOM AND THE SAFETY PRACTITIONER

The organizational safety practitioner must take a personal interest in ensuring that the facility is in full compliance with the Hazard Communication Standard for three major reasons: (1) it is the law; (2) it is consistently the number one cause of citations issued by OSHA for noncompliance; and (3) compliance with the standard goes a long way toward protecting workers, saving lives and money.

Sample Written Hazard Communication Program

I. Introduction

The OSHA Hazard Communication Standard was promulgated to ensure that all chemicals in the workplace are evaluated, and that information

Did You Know?

Trade secrets are protected under the Hazard Communication standard. The standard allows the chemical manufacturer, importer, or employer to withhold the specific chemical identity, including the chemical name and other specific identification of a hazardous chemical, from the MSDS under certain conditions. However, the manufacturer, importer, or employer must alert employees to any potential hazards.

regarding the hazards of these chemicals is communicated to employers and employees. The goal of the standard is to reduce the number of chemically related occupational illnesses and injuries.

This written program has been established for XYZ Industries to comply with the Hazard Communication Standard. All departments and work centers of XYZ are included within this program. Copies of this written program are available for review by any employee in the following locations:

(List all locations.)

Department Standard Operating Procedures (SOPs) work in conjunction with this basic document in providing the safest possible environment to all employees.

II. Responsibilities

- A. Department directors are responsible for implementing and ensuring the compliance of their departmental personnel with XYZ's Hazard Communication Program. Additionally, they assign appropriate supervisors with the responsibility of ensuring compliance.
- B. XYZ's safety director has the following responsibilities under XYZ's Hazard Communication Program:
 - 1. Develop and modify as necessary XYZ's Hazard Communication Program.
 - 2. Annually check and review the effectiveness of the overall program and all work center programs.
 - 3. Inspect quarterly each work center's Hazardous Chemical Inventory List and corresponding Material Safety Data Sheets to ensure they are current and complete.
 - 4. Receive and review all incoming or updated editions of MSDSs and distribute them to pertinent work centers.
 - 5. Maintain a current master MSDS file.
 - 6. Train supervisors in requirements for the Hazard Communication Program and assist in training personnel as required.
- C. Assigned supervisors have the following responsibilities under XYZ's Hazard Communication Program:
 - 1. Report receipt of all new chemicals to Safety Division.
 - 2. Ensure that no chemical is used at the work center until it is listed on the Hazardous Chemical Inventory List, the correspon-

- ding MSDS is inserted into the "Right-to-Know" Station Binder, and each employee has received the appropriate HazCom training.
3. Maintain current work center "Right-to-Know" work stations, which includes ensuring the MSDSs and Chemical Inventory List are current and accurately reflect chemicals used on-site.
 4. Ensure proper labeling practices for all hazardous chemicals in accordance with this program.
 5. Forward to the Safety Division all MSDSs received from sources other than the Safety Division.
 6. Ensure that every employee is trained on this program and the hazards involved with chemicals used in the work center.
 7. Ensure that all on-site contractors receive copies of the Hazard Communication Program and all work center MSDSs. In turn, the work center supervisor is responsible for obtaining MSDSs from contractors for chemicals brought to the site that XYZ employees may be exposed to.
- D. XYZ personnel are responsible for familiarizing themselves with the Hazard Communication Program, and complying with instructions contained with the Hazard Communication Program.

III. Definition of Terms

The Hazard Communication Program defines various terms as follows. (These terms either appear in XYZ's Hazard Communication Program or are definitions appropriate to MSDSs.)

Chemical: any element, compound, or mixture of elements and/or compounds.

Chemical name: 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.

Combustible liquid: any liquid having a flashpoint at or above 100°F (37.8°C), but below 200°F (93.3°C).

Common name: any designation or identification, such as code name, code number, trade name, brand name, or generic name used to identify a chemical other than its chemical name.

Compressed gas: a gas or mixture of gases in a container having an absolute pressure exceeding 40 psi at 70°F (21.1°C); a gas or mixture of gases in a container having an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C); or a liquid having a vapor pressure exceeding 10 psi at 100°F (37.8°C), as determined by ASTM D-323-72.

Container: any bag, barrel, bottle, box, can, cylinder, drum, reaction vessel, storage tank, or the like that contains a hazardous chemical.

Explosive: a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.

Exposure: the actual or potential subjection of an employee to a hazardous chemical through any route of entry, in the course of employment.

Flammable aerosol: 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 (flame extending back to the valve) at any degree of valve opening.

Flammable gas: a gas that at ambient temperature and pressure forms a flammable mixture with air at a concentration of 13 percent by volume or less, or a gas that at ambient temperature and pressure forms a range of flammable mixtures with air wider than 12 percent by volume regardless of the lower limit.

Flammable liquid: a liquid with a flashpoint of 100°F (37.8°C).

Flammable solid: a solid, other than a blasting agent or explosive as defined in 29 CFR 1910.109 (a), that is likely to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited, and that 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.

Flashpoint: the minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite.

Hazard warning: any words, pictures, symbols, or combination thereof appearing on a label or other appropriate form of warning that conveys the hazards of the chemical(s) in the container.

Hazardous chemical: any chemical that poses a health or physical hazard.

Hazardous Chemical Inventory List: an inventory list of all hazardous chemicals used at the site, and containing the date of each chemical's MSDS insertion.

Health hazard: a chemical, for which statistically significant evidence exists, based on at least one study conducted in accordance with established scientific principles, that acute or chronic health effects may occur in exposed employees.

Immediate use: the use under the control of the person who transfers the hazardous chemical from a labeled container, and only within the work shift in which it is transferred.

Label: any written, printed, or graphic material displayed on or affixed to containers or hazardous chemicals.

Material Safety Data Sheet (MSDS): the written or printed material concerning a hazardous chemical, developed in accordance with 29 CFR 1910.

Mixture: any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.

NFPA hazardous chemical label: a color-coded labeling system developed by the National Fire Protection Association (NFPA), which rates the severity of the health hazard, fire hazard, reactivity hazard, and special hazard of the chemical.

Organic peroxide: an organic compound that contains the bivalent O-O structure and that 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.

Oxidizer: a chemical, other than a blasting agent or explosive as defined in 29 CFR 1910.198 (a), that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

Physical hazard: a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water reactive.

Portable container: a mobile storage vessel, such as a drum, side-mounted tank, tank truck, or vehicle fuel tank.

Primary route of entry: the primary means (such as inhalation, ingestion, skin contact, etc.) whereby an employee is subjected to a hazardous chemical.

Pyrophoric: a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.

“Right-to-Know” Station Binder: a binder located in the “Right-to-Know” work station that contains XYZ’s Hazard Communication Program, the Hazardous Chemicals Inventory List and corresponding MSDSs, and the Hazard Communication Program review and signature form.

“Right-to-Know” work station: a central information work station where employees have access to site MSDSs, the Hazardous Chemical Inventory List, and XYZ’s written Hazard Communication Program.

Stationary container: a permanently mounted chemical storage tank.

Unstable (reactive) chemical: a chemical that in its pure state or as produced or transported will vigorously polymerize, decompose, condense, or become self-reactive under conditions of shock, pressure, or temperature.

Water reactive chemical: a chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

Work center: any convenient or logical grouping of designated unit processes or related maintenance actions.

IV. “Right-to-Know” Work Stations

Each work center has established and maintains an employee “Right-to-Know” work station. This “Right-to-Know” work station is accessible to employees during their work hours. The “Right-to-Know” work station contains a “Right-to-Know” Station Binder. This binder contains XYZ’s Hazard Communication Program, Hazardous Chemical Inventory List

and corresponding MSDSs, and the Hazard Communication Program review and signature form.

V. Hazardous Chemical Inventory List

A list of all hazardous chemicals or fuels used or produced at each work center is maintained in each work center’s Hazardous Chemical Inventory List. This Hazardous Chemical Inventory List is filed in the front of each work center’s “Right-to-Know” Station Binder, which is maintained within its “Right-to-Know” work station.

The Hazardous Chemical Inventory List also shows the date of the most recent MSDS insertion for each chemical. Only the hazardous chemicals or fuels actually used within each work center are listed in that work center’s Hazardous Chemical Inventory List. XYZ’s master Hazardous Chemical Inventory List for all chemicals used within XYZ is maintained by the Safety Division.

Each work center supervisor is to ensure that its Hazardous Chemical Inventory List is accurate, updated, and available for employee use. Work centers receiving new chemicals or chemicals not on their current Hazardous Chemical Inventory List shall follow these procedures:

- a. Add the hazardous chemical to the Hazardous Chemical Inventory List.
- b. Procure and insert the chemical MSDS into the “Right-to-Know” Station Binder.
- c. Train employees on the hazards associated with the chemical.

The Hazardous Chemical Inventory List for each work center is reviewed by each work center at least quarterly, and a verifying signature for this quarterly review is made on the Hazardous Chemical Inventory List. The Hazardous Chemical Inventory List (see figure 5.3) for

HAZARDOUS CHEMICAL INVENTORY LIST FORM

WORK CENTER:

CHEMICAL	DATE OF MSDS INSERTION

Figure 5.3. Hazardous Chemical Inventory List form.

each work center is reviewed quarterly by the Safety Division to ensure it is current, and that corresponding MSDSs are available.

VI. Material Safety Data Sheet (MSDS)

The Material Safety Data Sheets (MSDSs) are a set of individual data sheets providing related safety information for each hazardous chemical used or produced at the work center. Material Safety Data Sheets are filed in each work center's "Right-to-Know" Station Binder, located in the "Right-to-Know" work stations. Each chemical listed on the Hazardous Chemical Inventory List must have a corresponding MSDS. MSDSs are provided to work centers by the Safety Division any time manufacturers forward new copies or new editions. Work center supervisors are responsible for ensuring that MSDSs are current and available for all chemicals listed on their work center's Hazardous Chemical Inventory List, and that chemicals are not used unless this information is available.

The Material Safety Data Sheets should contain information as follows:

- a. Identity of hazardous chemical.
- b. Identity of hazardous ingredients in a hazardous chemical mixture.
- c. Chemical and physical characteristics of the hazardous chemical.
- d. Chemical and physical hazards of the hazardous chemical.
- e. Acute and chronic health hazards, including signs and symptoms of exposure and medical conditions that are generally aggravated by exposure to the hazardous chemical.
- f. Primary route of entry.
- g. Personal exposure limits in terms of maximum duration and concentration.
- h. Protective measures and special precautions.
- i. Emergency procedures and first aid procedures.
- j. Date of preparation of the Material Safety Data Sheet.
- k. Identification of person or agency responsible for the information contained on the Material Safety Data Sheet.

The Material Safety Data Sheet shall not contain any blank spaces. Not applicable or unknown information should be indicated as such.

The Purchasing Department shall specify that MSDSs are required with all orders. Supervisors using local supply orders (LSOs) to obtain chemicals should ensure that an MSDS is available for the product prior to or at receipt of the product.

Any MSDS received by the work center should be forwarded to the Safety Division with notations on which work center forwarded the sheet, and an indication as to whether the chemical is in use or not. If the work center is using a chemical without an existing MSDS, notify the Safety Division immediately. The Safety Division will procure the needed MSDS or generate a generic form. The Safety Division reviews

all incoming or self-generated MSDSs for completeness before forwarding copies to pertinent work centers.

VII. Hazard Warnings and Labeling

Hazard warnings are individual warnings on hazardous chemical containers that provide related safety information for each respective hazardous chemical used or produced within XYZ.

1. Hazard warnings should be displayed on or affixed to *all* hazardous chemical containers, providing the information as follows:

Note: XYZ personnel should not remove or deface existing hazard warnings or labels on hazardous chemical containers received or used at the work center, unless the container is immediately marked with the required information.

- a. *Each portable container* should be labeled, tagged, or otherwise marked as follows:
 1. Chemical or common name of the hazardous chemical.
 2. Hazard warnings.
 3. Name and address of the chemical manufacturer.

Note: XYZ supervisors should verify that all containers received for use are appropriately labeled.

- b. *Each stationary container* shall be labeled as follows:
 1. Chemical or common name of the hazardous chemical stenciled with six (6)-inch block letters.
 2. NFPA Hazardous Chemical Label.
- c. Where applicable, all *chemical piping* should be labeled in accordance with the Piping Identification Code or with standard industry color codes. (HazCom does not require the labeling of pipes, but when they contain hazardous chemicals, labeling is recommended.)
 2. NFPA Hazardous Chemical Labels should be affixed to hazardous chemical containers wherever appropriate and/or informative.
 3. NFPA "0-4" number rating system for each chemical can be obtained from the Safety Division.

VIII. Training

The Hazard Communication Program requires periodic training of XYZ personnel to ensure that the program requirement's safety precautions are properly conducted. Supervisors should consider personnel training as a primary responsibility.

- A. The Hazard Communication Program training duties and responsibilities for XYZ personnel are established as follows:
 - 1. The Safety Division is responsible for training supervisors in the program requirements, and is available by appointment to present to work center personnel the required Hazard Communication Program brief.
 - 2. XYZ supervisors are responsible for training XYZ personnel in the program requirements.
 - 3. XYZ personnel are responsible for familiarizing themselves with the program requirements.
- B. The Hazard Communication Program training should be planned so that:
 - 1. Training is given both in the program requirements and in related safety information, including protective measures, special precautions, and emergency procedures.
 - 2. Training is given both in the classroom and by on-the-job training.
 - 3. Training is given that uses group participation during both discussion and question-and-answer periods.
 - 4. Training is ongoing, to preserve the continuity and integrity of program and work center safety.
- C. The Hazard Communication Program training will be provided as follows:
 - 1. Training is conducted prior to assignment of a new employee to his or her work duties.
 - 2. Training is conducted whenever a new hazardous chemical is used or produced at the work center.
 - 3. Training is conducted prior to starting work on non-routine tasks involving hazardous chemicals.
- D. The Hazard Communication Program training is conducted by the supervisor, according to the recommended outline below:
 - 1. Locate and identify the Hazard Communication Program, the Hazardous Chemical Inventory List, and Material Safety Data Sheets, contained in the "Right-to-Know" work stations.
 - 2. Discuss the objective and content of the Hazard Communication Program.
 - 3. Explain that the Hazardous Chemical Inventory List lists *all* hazardous chemicals at the work center concerned.
 - 4. Discuss the physical and health effects of each hazardous chemical at the individual work center as contained in the MSDS.
 - 5. Discuss the methods and techniques used to determine the presence or release of hazardous chemicals at the individual work center.
 - 6. Discuss the protective measures and special precautions used to lessen or prevent exposure to hazardous chemicals at the individual work center.
 - 7. Discuss emergency procedures for each hazardous chemical at the individual work center as contained in the MSDS.
 - 8. Discuss the hazardous warning and labeling system.

XYZ'S EMPLOYEE TRAINING RECORD			
HAZARD COMMUNICATION TRAINING			
Date	Employee Name	Work center	
Trainer			DATE

Figure 5.4. XYZ's employee training record.

NOTE: Hazard Communication Program training is recorded in each employee training record (see figure 5.4); these records are examined during the Safety Division's quarterly safety inspections.

IX. On-Site Contractors/Visitors

1. XYZ work center supervisors and the Engineering Division should notify all contractors, vendors, etc., performing work within XYZ work centers of the Hazard Communication Program as follows:
 - a. The Safety Division, when directed by the work center supervisor/ Engineering Division, will provide a copy of XYZ's Hazard Communication Program to regulatory agencies, consulting engineers, contractors, etc., as appropriate upon their *initial visit* on-site to perform each specific project.

Note: A copy of the Hazard Communication Program should be provided upon the initial visit for each specific project. Providing additional copies for ongoing visits to accomplish the same specific project is not necessary.

- b. All written requests for proposals or quotations, all written specifications, and all written contracts and work orders should include a written notification of the Hazard Communication Program as follows:

XYZ is required in accordance with 29 CFR 1910.1200 to inform XYZ and contractor personnel that work centers within XYZ have hazardous chemicals on-site. XYZ and contract personnel may be exposed to these hazardous chemicals while working at XYZ work centers. A written Hazard Communication Program has been developed to inform person-

nel of the specific hazardous chemicals at the work center, and the related safety information, including protective measures, special precautions, and emergency procedures to be observed. The Hazard Communication Program, including a Material Safety Data Sheet (MSDS) for each hazardous chemical at the work center, will be made available to contractors. Contractors are responsible for communicating the information contained in the MSDSs to their personnel working at the work center.

2. Providing a copy of the Hazard Communication Program to other supervisors or personnel outside of the work center is the *responsibility of work center supervisors*. Familiarizing themselves and their personnel with the objective and content of the Hazard Communication Program is the *responsibility of other supervisors or personnel* outside the work center. Whenever XYZ personnel visit another work center to perform maintenance, provide assistance, or other activity, they should acquaint themselves with the information contained in the work center's "Right-to-Know" work station.

The work center supervisor should provide a copy of the Hazard Communication Program and training to the other XYZ departments and personnel as appropriate.

HAZCOM AUDIT ITEMS

If your facility has a written HazCom Program similar to the one in the sidebar, you are well along the road toward compliance. If your HazCom Program is audited by OSHA, the goal, of course, is for any auditor who might visit your facility to be able to readily see that you're in compliance. Often an auditor will not even review your written HazCom Program if he or she can plainly see you are in compliance.

Let's take a look at some of the HazCom items OSHA will be looking at. You must be able to answer "yes" to each of the following items, if site-applicable:

- Are all chemical containers marked with contents' name and hazards?
- Are storage cabinets used to hold flammable liquids labeled "Flammable—Keep Fire Away?"
- For a fixed extinguishing system, is a sign posted warning of the hazards presented by the extinguishing medium?
- Are all aboveground storage tanks properly labeled?
- If you store hazardous materials (including gasoline) in aboveground storage tanks, are tanks or other containers holding hazardous materials appropriately labeled with chemical name and hazard warning?
- Are all chemicals used in spray-painting operations correctly labeled?
- If you store chemicals, are all containers properly labeled with chemical name and hazard warning?

Along with checking these items, the OSHA auditor will make notes on the chemicals he or she finds in the workplace. When the walk-around is completed, the auditor will ask you to provide a copy of the MSDS for each chemical in his or her notes.

To avoid a citation, you must not fail this major test. If the auditor, for example, noticed during the walk-around that employees were using some type of solvent or cleaning agent in the performance of their work, he or she will want to see a copy of the MSDS for that particular chemical. If you can't produce a copy, you are in violation and will be cited. Be careful on this item—it is one of the most commonly cited offenses. Obviously, the only solution to this problem is to ensure that your facility has an MSDS for each chemical used, stored, or produced, and that your chemical inventory list is current and accurate. Save yourself a big hassle—ensure that an MSDS is available to employees for each chemical used on-site.

Keep in mind that the OSHA auditor will look at each work center within your company, and that each different work center will present its own specialized requirements. If your company has an environmental laboratory, for example, the auditor will spend considerable time in the lab, ensuring you are in compliance with OSHA's Laboratory Standard, and that you have a written Chemical Hygiene Plan.

References and Recommended Reading

- Meyer, E. 2005. *Chemistry of hazardous materials*. 4th ed. Upper Saddle River, N.J.: Prentice Hall.
- Moran, M. M. 1996. *OSHA's Hazard Communication Standard*. Rockville, Md.: Government Institutes.
- Spellman, F. R. 1998. *Surviving an OSHA audit*. Lancaster, Pa.: Technomic Publishing.

CHAPTER 6

Process Safety Management and Risk Management Planning

Unexpected releases of toxic, reactive, or flammable liquids and gases in processes involving highly hazardous chemicals have been reported for many years. Incidents continue to occur in various industries that use highly hazardous chemicals which may be toxic, reactive, flammable, or explosive, or may exhibit a combination of these properties. Regardless of the industry that uses these highly hazardous chemicals, there is a potential for an accidental release any time they are not properly controlled. This, in turn, creates the possibility of disaster.

Recent major disasters include the 1984 Bhopal, India, incident resulting in more than 2,000 deaths; the October 1989 Phillips Petroleum Company, Pasadena, Texas, incident resulting in 23 deaths and 132 injuries; the July 1990 BASF, Cincinnati, Ohio, incident resulting in 2 deaths, and the May 1991 IMC, Sterlington, Louisiana, incident resulting in 8 deaths and 128 injuries.

Although these major disasters involving highly hazardous chemicals drew national attention to the potential for major catastrophes, the public record is replete with information concerning many other less notable releases of highly hazardous chemicals. Hazardous chemical releases continue to pose a significant threat to employees and provide impetus, internationally and nationally, for authorities to develop or consider developing legislation and regulations to eliminate or minimize the potential for such events.

On July 17, 1990, the Occupational Safety and Health Administration (OSHA) published in the Federal Register (55 FR 29150) a proposed standard—"Process Safety Management of Highly Hazardous Chemicals"—containing requirements for the management of hazards associated with processes using highly hazardous chemicals to help assure safe and healthful workplaces.

. . . Approximately four months after the publication of OSHA's proposed standard for process safety management [PSM] of highly hazardous chemicals, the Clean Air Act Amendments (CAAA) were enacted into law (November 15, 1990). Section 304 of the CAAA requires that the Secretary of Labor, in coordination with the

Administrator of the Environmental Protection Agency (EPA), promulgate, pursuant to the Occupational Safety and Health Act of 1970, a chemical process safety standard to prevent accidental releases of chemicals that could pose a threat to employees.

. . . Also the CAAA identifies specific duties for EPA relative to the prevention of accidental releases. Generally, EPA must develop a list of chemicals and a Risk Management Plan (RMP).

—OSHA 3132 (1994)

Process Safety Management (PSM)

The impetus for OSHA's introduction of the Process Safety Management (PSM) Standard 29 CFR 1910.119 was the pressing need to address the ongoing occurrence of serious accidents at chemical processing plants (Spellman 1997).

Currently, the reality is that Process Safety Management (PSM) is addressed in several specific standards for the general and construction industries. OSHA's standard emphasizes the management of hazards associated with highly hazardous chemicals and establishes a comprehensive management program that integrates technologies, procedures, and management practices (Spellman 1998).

OSHA Standards Applicable to Process Safety Management (PSM)

GENERAL INDUSTRY (29 CFR 1910)

- 1910 Subpart H, Hazardous materials
 - Appendix A, List of highly hazardous chemicals, toxics, and reactives
 - Appendix B, Block flow diagram and simplified process flow diagram
 - Appendix C, Compliance guidelines and recommendations for process safety management
 - Appendix D, Sources of further information
- 1926 Subpart D, Occupational health and environmental controls
- 1926.64, Process safety management of highly hazardous chemicals
 - Appendix A, List of highly hazardous chemicals, toxics, and reactives
 - Appendix B, Block flow diagram and simplified process flow diagram
 - Appendix C, Compliance guidelines and recommendations for process safety management

PSM Definitions

Before beginning a discussion of PSM, it is important to define key terms used in the 29 CFR 1910.119 standard.

- **Boiling point:** the boiling point of a liquid at a pressure of 14.7 pounds per square inch absolute (psia) (760 mm).
- **Catastrophic release:** a major, uncontrolled emission, fire, or explosion involving one or more highly hazardous chemicals that presents serious danger to employees in the workplace.
- **Facility:** the buildings, containers, or equipment that contain a process.
- **Highly hazardous chemical:** substance possessing toxic, reactive, flammable, or explosive properties.
- **Hot work:** work involving electric or gas welding, cutting, brazing, or similar flame- or spark-producing operations.
- **Normally unoccupied remote facility:** a facility operated, maintained, or serviced by employees who visit the facility only periodically to check its operations and to perform necessary operating or maintenance tasks. No employees are permanently stationed at the facility. Facilities meeting this definition are not contiguous with, and must be geographically remote from, all other buildings, processes, or persons.
- **Process:** any activity involving a highly hazardous chemical, including any use, storage, manufacturing, handling, or the on-site movement of such chemicals or combination of these activities. For purposes of this definition, any group of vessels that are interconnected, and separate vessels that are located so that a highly hazardous chemical could be involved in a potential release, shall be considered a single process.
- **Replacement in kind:** a replacement that satisfies the design specification.
- **Trade secret:** any confidential formula, pattern, process, device, information, or compilation of information that is used in an employer's business, and that gives the employer an opportunity to obtain an advantage over competitors who do not know or use it.

How the Standard Works: Application

The Process Safety Management Standard (PSM) was promulgated by OSHA and has been in effect since February 1992. All covered facilities were required to be in compliance by May 1997. The regulation is intended to prevent or minimize the consequences of a catastrophic release of toxic, reactive, flammable, or explosive highly hazardous chemicals from a process (i.e., those chemicals listed under the regulation). A process is any activity or combination of activities including any use, storage, manufacturing, handling, or the on-site movement of highly hazardous chemicals. A process includes any group of vessels that are interconnected, and separate vessels that are located so that a highly hazardous chemical could be involved in a potential release. Note that the EPA has adopted PSM as a major component of its Risk Management Plan.

The standard applies to a process that contains a threshold quantity or greater amount of toxic or reactive highly hazardous chemicals as specified in appendix A of the standard. It also applies to ten thousand or more pounds of flammable liquids and gases, and to the process activity of manufacturing explosives and pyrotechnics.

The standard does allow exceptions. For example, the standard does not apply to retail facilities, normally unoccupied remote facilities, or to oil or gas well drilling or servicing activities. Hydrocarbon fuels used solely for workplace consumption as a fuel are not covered, if such fuels are not part of a process containing another highly hazardous chemical covered by the standard. Atmospheric tank storage and associated transfer of flammable liquids that are kept below their normal boiling point without benefit of chilling or refrigeration are not covered by the PSM standard, unless the atmospheric tank is connected to a process or is sited in proximity to a covered process, so that an incident in a covered process could involve the atmospheric tank.

Both municipal and industrial covered facilities must comply with PSM. If any process in your facility contains or manufactures any of the covered chemicals (a partial listing is provided in table 6.1) at quantities at the threshold or greater, a Process Safety Management Program must be implemented. The threshold quantity is defined as the total quantity of material in the process that can potentially be released during an abnormal process situation.

Process Safety Management is designed to help the facility function safely, and to promote better quality through elimination of process fluctuations and process shut-downs, by eliminating unsafe changes from normal operating practice. Also, PSM is designed to identify operations that are not operating properly. Simply put, through PSM, a determination is made on how to perform and maintain operations safely.

PSM requires all covered facilities to develop and maintain written safety information about hazardous processes. This information should cover the hazards of the chemicals being used or produced. The Material Safety Data Sheet (MSDS) is probably the best source of information. Along with the MSDS, information is also required on the process technology. Such items as flow diagrams, piping and instrumentation diagrams (P&IDs), and safety-operating limits of temperature, flow rate, and pressure should be provided. Information data on electrical classification, design codes, and applicable standards should all be available to plant operators.

Table 6.1 PSM-Covered Chemicals/Materials (partial listing)

<i>Chemical</i>	<i>Threshold Quantity</i>
Chlorine	1,500 lbs.
Sulfur dioxide	1,500 lbs.
Biogas	10,000 lbs.
Biosolids	10,000 lbs.
Ozone	100 lbs.
Flammables (polymers, etc.)	10,000 lbs.
Hydrogen sulfide	1,500 lbs.
Ammonia solution	10,000 lbs.
Flammable liquids or gases (such as propane, methane, oil)	10,000 lbs.
Hydrogen peroxide	@52% 7,500 lbs.
Chlorine dioxide	1,000 lbs.
Hydrochloric acid	5,000 lbs.
Oxygen	10,000 lbs.

Note: For the entire listing see 29 CFR 1910.119.

To identify the potential hazards in your chemical processes, a process hazard analysis (PHA) must be conducted. The facility should set up a team to conduct facility investigations and evaluations on processes that might be dangerous. This hazard analysis team should focus on the location of each process area, the hazards of the process, the probable outcome if controls fail, and the possibility of human error. The prudent facility manager makes a careful review of the plant's historical record concerning previous incidents—those that caused or could have caused catastrophic results. When the analysis is completed and recommendations have been issued to management for resolving the safety issues identified, this document becomes a permanent plant record that should be updated every five years.

PSM requires each facility to develop written standard operating procedures (SOPs) for each covered process. SOPs should describe the steps of each phase of the operation, the operating limits of the process, how to avoid exceeding limits, safety systems and how they operate, and hazard control for confined space entry and line-breaking activities.

Before work begins on any new facility chemical process, workers must be thoroughly trained on how to conduct each process step as safely as possible. Training should specifically focus on operating procedures, on process-specific safety and health hazards, on emergency operations and shutdowns, and on applicable safe work practices. Follow-up refresher training must be completed every three years. Again, make sure to document the training.

One of the interesting requirements of the PSM standard deals with outside contractors. Contract workers who work on the facility are exposed to the same hazardous processes as plant personnel. PSM spells out the duties of the host (employing facility) and the contractor. Some of the specific duties of the host include:

- informing the contractor of the potential hazards
- explaining the plant's emergency response procedures
- evaluating the contractor safety record and programs (Note: OSHA requires facilities that employ outside contractors to perform work in or around a covered process to be screened to ensure that the contractor can complete assigned work without compromising worker safety and health.)
- conducting safety audits on the construction site

Some of the contractor's specific duties include:

- ensuring that contract employees follow the host facility's safety rules
- informing contract workers of the process hazards and the facility's emergency response plan
- ensuring that each contract worker has been properly trained to perform his or her job safely

PSM mandates several other requirements. It requires the use of hot work permits, for example. Whenever hot work (welding, grinding, brazing, or burning) is performed on or near a covered process, the danger exists that heat generated by the hot work will

change the process. This change might be extremely dangerous. Welding on a digester methane line, for example, could bring about changes to the process that could destroy the entire site and kill many workers. The hot work permit should verify that necessary fire-prevention measures have been taken.

When working with outside contractors, get off on the right foot before construction begins. PSM requires the host to inform the outside contractor of the hazards and/or potential hazards of the plant site. This can be accomplished by briefing the contractor senior personnel prior to the start of construction.

Specific PSM Requirements

OSHA Process Safety Management Standard consists of sixteen elements. The first two (called Applications and Definitions) are introductory only; the other fourteen (listed below) are required to be complied with by covered facilities (if applicable). The required elements are:

- Employee participation
- Process safety information
- Process hazard analysis
- Operating procedures
- Training
- Contractors
- Pre-startup safety review
- Mechanical integrity
- Hot work permit
- Management of change
- Incident investigation
- Emergency response planning and response
- Compliance audits
- Trade secrets

Using the information provided in OSHA's Fact Sheet 93-45, let's take a closer look at each of these elements:

- **Employee involvement:** requires developing a written plan of action regarding employee participation; consulting with employees and their representatives on the conduct and development of process hazard analyses and on the development of other elements of process safety management required under the rule; providing to employees and their representatives access to process hazard analyses and to all other information required to be developed under the rule. Includes work site and contractor employees.
- **Process safety information:** requires compilation of written process safety information, including hazard information on highly hazardous chemicals, technology information, and equipment information on covered processes.

- **Process hazard analysis (PHA):** specifies that process hazard analyses (PHAs) must be conducted as soon as possible for each covered process, using compiled process safety information and data in an order based on a set of required considerations. Process hazard analyses must be updated and revalidated at least every five years and must be retained for the life of the process.
- **Operating procedures:** must be in writing and must provide clear instructions for safely conducting activities involving covered processes consistent with process safety information; must include steps for each operating phase, operating limits, safety and health considerations, and safety systems and their functions; must be readily accessible to employees who work on or maintain a covered process, and be reviewed as often as necessary to assure they reflect current operating practice; and must implement safe work practices to provide for special circumstances such as lockout/tagout and confined space entry.
- **Training:** employees operating a covered process must be trained in the overview of the process and in the operating procedures addressed previously. This training must emphasize specific safety and health hazards, emergency operations, and safe work practices. Initial training must occur before assignment or employers may certify that employees involved in the process as of May 26, 1992, have the required knowledge, skills, and abilities. Documented refresher training is required at least every three years.
- **Contractors:** identifies responsibilities of work site employer and contract employers with respect to contract employees involved in maintenance, repair, turnaround, major renovation, or specialty work, on or near covered processes. Contract employers are required to train their employees to safely perform their jobs, document that employees received and understood training, and assure that contract employees know about potential process hazards and the work site employer's emergency action plan, assure that employees follow safety rules of the facility, and advise the work site employer of hazards contract work itself poses or hazards identified by contract employees.
- **Pre-startup safety review:** mandates a safety review for new facilities and significantly modified work sites to confirm that the construction and equipment of a process are in accordance with design specifications; to assure that adequate safety, operating, maintenance, and emergency procedures are in place; and to assure process operator training has been completed. Also, for new facilities, the PHA must be performed and recommendations resolved and implemented before startup. Modified facilities must meet management of change requirement.
- **Mechanical integrity:** requires the on-site employer to establish and implement written procedures for the ongoing integrity of process equipment, particularly those components that contain and control a covered process.
- **Hot work:** hot work permits must be issued for hot work operations conducted on or near a covered process.
- **Management of change:** the work site employer must establish and implement written procedures to manage changes except "replacement in kind" to facilities that affect a covered process. The standard requires the work site employer and contract employers to inform and train their affected employees on the changes

prior to startup. Process safety information and operating procedures must be updated as necessary.

- **Incident investigation:** requires employers to investigate as soon as possible (but no later than 48 hours after) incidents that did result or could reasonably have resulted in catastrophic releases of covered chemicals. The standard calls for an investigation team, including at least one person knowledgeable in the process involved (a contract employee when the incident involved contract work), and others with knowledge and experience to investigate and analyze the incident, and to develop a written report on the incident. Reports must be retained for five years.
- **Emergency planning and response:** requires employers to develop and implement an emergency action plan. The emergency action plan must include procedures for handling small releases.
- **Compliance audits:** calls for employers to certify that they have evaluated compliance with process safety requirements at least every three years. Prompt response to audit findings and documentation that deficiencies are corrected is required. Employers must retain the two most recent audit reports.
- **Trade secrets:** sets requirements similar to trade secret provisions of the 1910.1200 Hazard Communication Standard requiring information required by the PSM standard to be available to employees (and employees' representatives). Employers may enter into confidentiality agreement with employees to prevent disclosure of trade secrets.

An essential part of determining the effectiveness of any compliance effort with PSM is verification of the flow of information and activities among the above elements. When information in one element is changed, or when action takes place in one element that affects other elements, a sample of the related elements should indicate if appropriate changes and follow-up actions have taken place or related elements can be affected.

Let's look at an example (provided by OSHA) that clearly demonstrates the inter-relationship among the elements.

Case Study 6.1. During a routine inspection of equipment (Mechanical Integrity), the maintenance worker discovered a valve that no longer meets the applicable code and must be changed. Because the type of valve is no longer made, a different type of valve must be selected and installed (Management of Change). The type of valve selected may mandate different steps for the operators (Operating Procedures) who will require training and verification in the new procedures (Training). The rationale for selecting the type of valve must be made available for review by employees and their representatives (Employee Participation).

When the new valve is installed by the supplier (Contractors), it will involve shutting down part of the process (Pre-startup Safety Review) as well as brazing some of the lines (Hot Work Permit). The employer must review the response plan (Emergency Planning) to ensure that procedures are adequate for the installation hazards.

Although Management of Change provisions cover interim changes, after the valve is in place the Process Safety Information will have to be updated before the Process Hazard Analysis is updated or revalidated, to account for potential hazards associated with the new equipment. Also, inspection and maintenance procedures and training will need to be updated (Mechanical Integrity).

A total of eleven PSM elements can be affected by changing one valve. If your PSM program is audited by OSHA, the auditor likely will check a representative sample of these eleven elements to confirm that the required follow-up activities have been implemented for the new valve, or any other similar process component.

The auditor, to ensure that changes have been implemented as required, will verify three key elements. They are:

- Operating procedures
- Process hazard analysis
- Training

The auditor will cross-check to see if changes have been followed through to completion.

In this general overview of PSM, we've only covered some of the requirements. Each facility that uses or produces chemicals must refer to 29 CFR 1910.119 for further guidance.

A Final Word on PSM

Having been involved with the PSM implementation process multiple times, we can state without reservation that it is a difficult but doable undertaking. In our experience, after process safety information is gathered, the most difficult PSM element to complete is the process hazard analysis (PHA). When done correctly, the PHA is a painstaking process that requires a certain amount of expertise, attention to detail, and considerable thought by those involved in the study.

Note: Though a few safety engineers we know have attempted to perform a PHA on their own, this process requires more than the lone-wolf approach—more than one person doing all the work. Moreover, OSHA does not allow this approach. Remember, OSHA insists that as an important part of PSM employees must participate in the process of formulating the organizational PSM program. Ideally, a review team, group, or PHA committee should be formed. The entity performing the PHA should consist of a cross-section of employee experience. Along with a professional engineer and seasoned operators, we recommend that others from many different job classifications be included in this process. Rule of thumb: To ensure employee participation, use the talents of several personnel to complete your organizational PHA.

Several methodologies (as described by the Center for Chemical Process Safety [CCPS]) or hazard evaluation procedures are available to complete the process hazard analysis. In an appendix to the PSM Standard, OSHA discussed several of these methods of process hazard analysis. That discussion, which may be helpful for those doing job hazard analyses, follows:

What-If: For relatively uncomplicated processes, review the process from raw materials to product. At each handling or processing step, “what-if” questions are formulated and answered, to evaluate the effects of component failures or procedural errors on the process.

Checklist: For more complex processes, the “what-if” study can be best organized through using a checklist, and assigning certain aspects of the process to the committee members with the greatest experience or skill in evaluating those aspects. The committee members audit operator practices and job knowledge in the field, study the suitability of equipment and materials of construction, review the chemistry of the process and control systems, and audit the operating and maintenance records. Generally, a checklist evaluation of a process precedes use of the more sophisticated methods described below, unless the process has been operated safely for many years and has been subjected to periodic and thorough safety inspections and audits.

What-If/Checklist: The what-if/checklist is a broadly based hazard assessment technique that combines the creative thinking of a selected team of specialists with the methodical focus of a prepared checklist. The result is a comprehensive hazard analysis that is extremely useful in training operating personnel on the hazards of the particular operation.

The review team is selected to represent a wide range of production, mechanical, technical, and safety disciplines. Each person is given a basic information package that concerns the operation to be studied. This package typically includes information on hazards of materials, process technology, procedures, equipment design, instrumentation control, incident exposure, and previous hazard reviews. A field tour of the operation also is conducted at this time.

The review team methodically examines the operation from receipt of raw materials to delivery of the finished product to the customer’s site. At each step, the group collectively generates a listing of “what-if” questions regarding the hazards and safety of the operation.

When the review team has completed listing its spontaneously generated questions, it systematically goes through a prepared checklist to stimulate additional questions. Subsequently, answers are developed for each question. The review team then works to achieve a consensus on each question and answer. From these answers, a listing of recommendations is developed specifying the need for additional action or study. The recommendations, along with the list of questions and answers, become the key elements of the hazard assessment report.

HAZOP and Operability Study (HAZOP): HAZOP is a formally structured method of systematically investigating each element of a system for all of the ways in which important parameters can deviate from the intended design conditions to create hazards and operability problems. The hazard and operability problems are typically determined by a study of the piping and instrument diagrams (or plant

model) by a team of personnel who critically analyze effects of potential problems arising in each pipeline and each vessel of the operation. Pertinent parameters are selected (for example, flow, temperature, pressure, and time), and then the effect of deviations from design conditions of each parameter is examined. A list of keywords (for example, “more of,” “less of,” “part of”) is selected for use in describing each potential deviation.

The system is evaluated as designed and with deviations noted. All causes of failure are identified. Existing safeguards and protection are identified. An assessment is made weighing the consequences, causes, and protection requirements involved.

Failure Mode and Effect Analysis (FMEA): The FMEA is a methodical study of component failures. This review starts with a diagram of the operation, and includes all components that could fail and conceivably affect the safety of the operation. Typical examples are instrument transmitters, controllers, valves, pumps, rotometers, and so forth. These components are listed on a data tabulation sheet and individually analyzed for the following:

- Potential mode of failure, (e.g., open, closed, on, off, leaks, etc.)
- Consequence of the failure; effect on other components and effects on whole system
- Hazard class (e.g., high, moderate, low)
- Probability of failure
- Detection methods
- Remarks/compensating provisions

Multiple concurrent failures also are included in the analysis. The last step in the analysis is to analyze the data for each component or multiple component failure and develop a series of recommendations appropriate to risk management.

Fault Tree Analysis: A fault tree analysis can be either a qualitative or quantitative model of all the undesirable outcomes (such as a toxic gas release or explosion) that could result from a specific initiating event. It begins with a graphic representation (using logic symbols) of all possible sequences of events that could result in an incident. The resulting diagram looks like a tree with many branches listing the sequential events (failures) for different independent paths to the top event. Probabilities (using failure rate data) are assigned to each event, then used to calculate the probability of occurrence of the undesired event. This technique is particularly useful in evaluating the effect of alternative actions on reducing the probability of occurrence of the desired event.

Risk Management Planning (RMP)

Community residents and industry officials do not consider the importance of accident prevention until after an accident occurs. . . . By then, the ghosts of Bhopal's victims must whisper, the only response can be: Too late. Too late.

—J. G. Minter (1996)

On May 24, 1996, the U.S. Environmental Protection Agency (EPA) finalized the Risk Management Program (RMP) under Section 112(r) of the 1990 Clean Air Act Amendments. On June 20, 1996, EPA promulgated the new rule. The rule, under 40 CFR Part 68, is entitled “Accidental Release Prevention Provisions: Risk Management Programs.” Covered sources had until June 21, 1999, to compile data, devise a Risk Management Plan, institute a Risk Management Program to comply with RMP and submit the Risk Management Plan to the EPA for review and approval.

Note: As with OSHA’s PSM, distinguishing between a plan and a program is important. Specifically, the plan is the *information* and the document that the facility submits to the regulatory agency (EPA for RMP) and maintains on-site for use by facility personnel. The program, however, is the *system* that backs up the plan, and helps to ensure that the facility is operated according to the rule. The viable program is more than just a vehicle to be used in improving the facility’s safety profile; it should also provide dividends in productivity, efficiency, and profitability. Keep in mind that to be beneficial (i.e., to reduce accidents and injuries), the program, as with any other management tool, must be upgraded and improved on a continuing basis.

Like OSHA’s Process Safety Management (PSM) Program, which is designed to protect workers from accidental releases of hazardous substances, the RMP rule addresses specific chemicals/materials (compounds); RMP addresses the accidental release of over 100 chemical substances that are listed in an appendix to the rule. The RMP chemicals listed include 77 acutely toxic chemical compounds, 63 flammable gases, and others. Threshold quantity levels range from 500 pounds to 20,000 pounds. EPA estimates that over 140,000 sources are covered by the rule. The universe includes chemical and most other manufacturers, certain wholesalers and retailers, drinking water systems, wastewater treatment works, ammonia refrigeration systems, chemical wholesalers and end users, utilities, propane retailers, and federal facilities.

Unlike PSM, RMP focuses on protecting those “outside the fence line”—that is, protecting the public and the environment are EPA’s primary focus, while OSHA’s primary focus is the safety and well-being of workers on the plant site (“inside the fence line”). Note that RMP does not apply to facilities that handle regulated substances in quantities below the specified threshold quantity levels.

RMP includes seven general requirements:

1. Submit a single RMP (written plan)
2. Executive summary
3. Registration form
4. Off-site consequence analysis (OCA)
5. Five-year accident history
6. Emergency response program
7. Certification statement

RMP also includes three major elements. These important elements include:

1. Hazard assessment. A hazard assessment is required to assess the potential effects of an accidental release of a covered chemical/material. This element generally includes performing an off-site consequence analysis (OCA) and the compilation of a five-year accident history. The OCA must include analysis of at least one worst-case scenario. It must also include one alternative release scenario for the flammable class as a whole, and each covered toxic substance must have an alternative release scenario. EPA has summarized some simplified consequence-modeling approaches in an OCA guidance document. This OCA guidance document contains tables of dispersion and explosion modeling results that allow those who use them to minimize modeling efforts.

In its modeling requirement, EPA has specified numerous mandatory modeling parameters and assumptions (primarily for the worst-case scenario analyses), to make OCAs more consistent. The worst-case scenario release quantity is defined as the largest vessel or pipe inventory (considering administrative controls) that could limit the maximum inventory before the release. Generally, gas releases are assumed to occur over a ten-minute period; liquid pools are assumed to form instantaneously and then vaporize. Passive mitigation system credit may be given if the system is capable of withstanding the release event. For flammable releases, the analyst must assume that the entire release quantity vaporizes and undergoes a vapor cloud explosion.

Worst-case scenario. When considering the stationary source's worst-case scenario, examine selection factors. In addition to the largest inventories of a substance, the following conditions must also be considered: smaller quantities handled at higher process temperatures and pressures, and proximity to the boundary of the stationary source. Sources must analyze and report additional worst-case scenarios for a hazard class if the worst-case scenario from another covered process affects a different set of public receptors than the original worst-case scenario.

Alternative release scenario. Alternative release scenarios must be more likely to occur than the worst-case scenario, and must reach an off-site endpoint. The EPA says owners should also consider these factors in selecting alternative release scenarios: five-year accident history and failure scenarios identified by a process hazard analysis (PHA) or Program Level 2 hazard review. The alternative release scenario analyses may be performed using somewhat more flexible modeling approaches and parameters than specified for worst-case scenario analyses. For example, active mitigation credit can be given.

Estimating distance. For both the worst-case and alternative release scenario, the source must estimate the distance to where the endpoint is no longer exceeded, and estimate the population (rounded to two significant digits) within a circle defined by the distance and centered at the release point. U.S. Census data may be used and does not have to be updated. However, the presence of sensitive populations (e.g., hospitals, schools, etc.) must be noted. The source must identify and list the types of environmental receptors within the calculated worst-case distance and circle, but no environmental damage assessment is required. In determining the presence of environmental receptors, U.S. Geological Survey maps may be used.

The off-site consequence analysis must be reviewed and updated every five years. However, if process changes might reasonably be expected to cause the worst-case scenario footprint or signature to increase or decrease by a factor of two or more, then the OCA must be revised and the risk management plan must be resubmitted to EPA or designated authority within six months.

Note that the five-year history must cover all accidental releases from covered processes that resulted in deaths, injuries, or significant property damage on-site, or known off-site deaths, injuries, evacuations, sheltering in place, property damage, or environmental damage. EPA requires that ten specific types of accident data be compiled, including known initiating events, off-site impacts, contributing factors, and operational or process changes that resulted from investigation of the release.

2. Prevention program. A prevention program is required to prevent accidental releases of regulated substances. This element generally includes safety precautions and maintenance, monitoring, employee safety training, and other requirements similar to OSHA's PSM. Note that EPA's requirements for the Program Level 2 elements (listed below) are less detailed than their OSHA PSM counterparts (other differences and similarities between RMP and PSM will be discussed later):

- Safety information
- Hazard reviews
- Compliance audits
- Maintenance
- Operating procedures
- Incident investigation
- Training

For example, the hazard review requirements have the following differences from OSHA's process hazard analysis provision:

- No team requirement for the review
- Fewer technical issues addressed in the analysis
- Results must be documented and problems resolved in a timely manner; no requirement for a formal resolution system
- No requirements to keep all hazard review results for the life of the process
- No requirement to communicate findings to employees

Although the prevention program language of RMP's Program Level 2 is somewhat different than the requirements in the OSHA PSM standard, this is not the case with the language of RMP's Program Level 3; it is virtually identical to that of the OSHA PSM standard, except that the RMP rule uses different terms for some things (to be discussed later). These differences are based on the different legislative authorities that each agency holds. EPA has also deleted specific phrases from the OSHA PSM regulatory language for the process safety information, process hazard analysis, and incident investigation elements to ensure that all sources implement process safety management in a way that protects not only workers but also the public and the environ-

ment. Because of this language difference, companies should incorporate consideration of off-site effects into their OSHA PHA revalidation protocols.

3. Response program. The response program equires specific action to be taken in emergency situations. This element generally includes procedures for notifying public and local agencies responsible for responding to accidental releases, information on emergency health care, and employee response training measures. These employee response training measures are required for plants whose employees are intended to respond to accidental releases using the plant's plan. The plan must address public notification, emergency medical treatment for accidental human exposures, and procedures of emergency response.

RMP Definitions and Requirements

The final management planning regulation (40 CFR part 68) defines the activities sources must undertake to address the risks posed by regulated substances in covered processes. All regulations have their own vocabulary. A few words and phrases have very specific meanings within the regulation. Some of these are unusual, which is to say they are not consistent with their everyday meaning. The following are the major regulatory terms used in this document and a brief introduction to their meaning within the context of part 68.

- **Environmental receptor:** a limited number of natural areas that are officially designated by the state or federal government.
- **Process:** the most confusing term in this rule. Most people think of a process as the mixing or reacting of chemicals. Its meaning under this rule is much broader. It basically means any equipment (including storage vessels) and activities (such as loading) that involve a regulated substance and could lead to an accidental release.
- **Public receptor:** in general, any place where people live, work, or gather, with the exception of roads. Buildings (such as houses, shops, office buildings, industrial facilities), the areas surrounding buildings where people are likely to be present (such as yards and parking lots), and recreational areas (such as parks, sports arenas, rivers, lakes, and beaches) are considered public receptors.
- **Regulated substance:** one of the 140 chemicals listed in part 68. Because so many chemicals are covered, and because each regulation covers a different set of chemicals and uses different phrases to identify the covered chemicals, 40 CFR 68 always uses "regulated substance" when talking about the chemicals subject to this rule.
- **Stationary source:** generally, facility, except where "facility" is used in its place in this document.
- **Threshold quantity:** the quantity (in pounds) of a regulated substance that triggers coverage by 40 CFR 68. Each regulated substance has its own threshold quantity. If you have more than a threshold quantity of a regulated substance in a process, you must comply with the rule.
- **Vessel:** any container, from a single drum or pipe to a large storage tank or sphere.

RMP Program Levels

To ensure that individual processes are subject to appropriate requirements that match their size and risks they may pose, EPA has classified them into three categories (programs). These program classifications are described in the following, along with the requirements for regulated processes in each category.

PROGRAM 1

Program 1 requirements apply to processes for which a worst-case release, as evaluated in the hazard assessment, would not affect the public. These sources or processes have not had an accidental release that caused serious off-site consequences. Remotely located sources and processes using listed flammables are primarily those eligible for this program.

Program 1 Requirements

- a. Hazard Assessment
 - Worst-case analysis
 - Five-year accident history
- b. Prevention Program
 - Certify no additional steps needed
- c. Emergency Response Program
 - Coordinate with local responders
- d. Risk Management Plan Contents
 - Executive summary
 - Registration
 - Worst-case data
 - Five-year accident history
 - Certification

PROGRAM 2

Program 2 requirements apply to less complex operations that do not involve chemical processing (e.g., retailers', propane users', non-chemical manufacturers' processes not regulated under OSHA's PSM Standard).

Program 2 Requirements

- a. Hazard Assessment
 - Worst-case analysis

- Alternative releases
- Five-year accident history
- b. Management Program
 - Document management system
- c. Prevention Program
 - Safety information
 - Hazard review
 - Operating procedures
 - Training
 - Maintenance
 - Incident investigation
 - Compliance audit
- d. Emergency Response Program
 - Develop plan and program
- e. Risk Management Plan Contents
 - Executive summary
 - Registration
 - Worst-case data
 - Alternative release data
 - Five-year accident history
 - Prevention program data
 - Emergency response data
 - Certification

PROGRAM 3

Program 3 requirements apply to higher risk, complex, chemical-processing operations, to sources having a relevant process in one of nine named Standard Industrial Classification (SIC) codes listed in table 6.2, or having a process or processes subject to the OSHA PSM (OSHA, 1996).

Table 6.2. Program 3—SIC Code Applicability

<i>Program 3—SIC code applicability</i>	
<i>SIC Code</i>	<i>Industry</i>
2611	Pulp mills
2812	Alkalis and chlorine
2819	Industrial inorganics
2821	Plastics and resins
2865	Cyclic crudes
2869	Industrial organics
2873	Nitrogen fertilizers
2879	Agricultural chemicals
2911	Petroleum refineries

Program 3 Requirements

- a. Hazard Assessment
 - Worst-case analysis
 - Alternative releases
 - Five-year accident history
- b. Management Program
 - Document management system
- c. Prevention Program
 - Process safety information
 - Process hazard analysis
 - Operating procedures
 - Training
 - Mechanical integrity
 - Incident investigation
 - Compliance audit
 - Management of change
 - Pre-startup review
 - Contractors
 - Employee participation
 - Hot work permits
- d. Emergency Response Program
 - Develop plan and program
- e. Risk Management Plan Contents
 - Executive summary
 - Registration
 - Worst-case data
 - Alternative release data
 - Five-year accident history
 - Prevention program data
 - Emergency response data
 - Certification

RMP and PSM: The Similarities and Overlap

Relating the comparison of RMP and PSM in the context of RMP versus PSM would be incorrect. The RMP rule and PSM standard are designed to work together; they complement each other. For example, OSHA PSM generally qualifies as meeting the RMP “prevention program” element. Remember that in PSM, process safety techniques employ systematic methods for evaluating a process system and identifying potential hazards. For instance, such techniques as checklists, “what-if” analyses, safety audit reviews, failure modes and effect analysis, fault tree analysis, event tree analysis, and hazard and operability studies (HAZOP) used to conduct the PHA for PSM, work well in satisfying the prevention program requirement of RMP.

Other complementary or similar elements are shared by the two regulations. For example, both regulations share the same goals: (1) to prevent the accidental releases of regulated substances and (2) to minimize the consequences of releases that do occur.

Additional similarities between RMP and PSM can be seen quite clearly if the facility under discussion or review is classified as a Program 3 facility. In a facility categorized at the Program 3 level, the following PSM elements must be implemented for a Program 3 covered facility's RMP program.

- Process safety information
- Compliance audits
- Process hazard analysis
- Incident investigation
- Operating procedures
- Employee participation
- Training
- Hot work permit
- Mechanical integrity
- Contractors
- Management of change
- Pre-startup review

Note that facilities classified as Program 2 facilities do not have to include the management of change, pre-startup review, employee participation, hot work permit, or contractors' elements of PSM into their RMP. To gain better appreciation of the similarities and differences, based on program level, between PSM and RMP, see table 6.3.

RMP and PSM: Differences

The previous section discussed and table 6.3 illustrated the similarities between RMP and PSM. In this section we discuss their differences. The first major difference between RMP and PSM is their origination. RMP is an EPA regulation. Along with its goal to reduce the harmful effects of accidental spills or releases, EPA targets (as we pointed out earlier) protection for those entities "outside the fenceline." That is, EPA is concerned with providing protection for the public—for those who do not live or work on the covered facility. PSM, an OSHA regulation, targets its regulatory power toward ensuring the protection of the worker—the personnel who work on the plant site. One could almost say that OSHA requires compliance inside the fenceline only, as if it were a solitary, isolated entity. EPA's RMP rule knocks down the fence.

This difference in philosophy of who is to be protected by a particular regulation, the public or the worker, actually works to ensure that both are protected, because facilities affected by RMP generally are also affected by the requirements of

Table 6.3. Comparison of Program Requirements

<i>Program 1</i>	<i>Program 2</i>	<i>Program 3</i>
Worst-case analysis	Worst-case analysis	Worst-case analysis
	Alternative releases	Alternative releases
5-year accident history	5-year accident history	5-year accident history
	Document management system	Document management system
Prevention program		
Certify no additional prevention steps needed	Safety information	Process safety information
	Hazard review	Process hazard analysis
	Operating procedures	Operating procedures
	Training	Training
	Maintenance	Mechanical integrity
	Incident investigation	Incident investigation
	Compliance audit	Compliance audit
		Management of change
		Pre-startup review
		Contractors
		Employee participation
		Hot work permits
		Emergency response program

Source: USEPA 40 CFR 68, 1996.

PSM. Simply stated, complying with the requirements of each regulation protects both the public and the worker, and the environment benefits as well.

The EPA's requirement to protect the public requires the covered facility to conduct an off-site consequence analysis (OCA). In PSM, the employer is only required to investigate each incident that resulted in or could have resulted in a catastrophic release of a highly hazardous chemical in the workplace.

Other differences between RMP and PSM include reporting requirements, and some of the terms and definitions used by EPA in RMP. For reporting requirements, under PSM, OSHA requires the covered facility to comply with all applicable paragraphs. This compliance is expected to be completed by the covered facility, but OSHA does not require the submission of a formal written document showing that compliance has been effected under PSM.

However, this is not the case with RMP. In addition to requiring full compliance by those facilities covered under the regulation, it also requires each source to submit a Risk Management Plan. Each source submitting its Risk Management Plan can do so (is encouraged to do so) via electronic transmission. Various preliminary models were available to aid in the collection of data required prior to June 21, 1999, the date when covered sources had to be in compliance with RMP, and a checklist is now available for electronic submission.

With the exception of some key terms and phrases, the Program 3 prevention program language in RMP is identical to the OSHA PSM language. Most of the differences are in terminology based on specific legislative authorities given to EPA or

Table 6.4. RMP/PSM Terms

<i>PSM term</i>	<i>RMP term</i>
Highly hazardous substance	Regulated substance
Employer	Owner or operator
Facility	Stationary source
Standard	Rule or part

Source: USEPA 40 CFR 68, 1996

OSHA that have essentially the same meaning. To illustrate these differences some of the RMP and PSM terms are listed in table 6.4.

In addition to using a few different key terms, RMP uses a few terms that are unique to the rule, or are borrowed from PSM. These terms include:

- **Off-site:** areas beyond the property boundary of the stationary source, or areas within the property boundary to which the public has routine and unrestricted access during or outside business hours. Note: OSHA's jurisdiction includes visitors that may be on the property of a facility who are conducting business as employees of other companies, but does not necessarily extend to casual visitors or to areas within a facility boundary to which the public has routine and unrestricted access at any time.
- **Significant accidental release:** any release of a regulated substance that has caused or has the potential to cause off-site consequences such as death, injury, or adverse effects to human health or the environment, or the potential to cause the public to shelter in place or be evacuated to avoid such consequences.
- **Stationary source:** EPA defined source to include the entire facility. Sources are still required to submit one RMP and one registration (to be discussed later) as part of that RMP for all processes at the source with more than a threshold quantity of a regulated substance.

Summary of RMP Requirements

The owner or operator of a stationary source that has more than a threshold quantity (TQ) of a regulated substance in a process must prepare and submit a single risk management plan (RMP) that covers all affected processes and chemicals:

- **Program Level 1:** Conduct a worst-case release scenario analysis, review accident history, ensure emergency response procedures are in place and coordinated with community officials.
- **Program Level 2:** Conduct a hazard assessment, document a management system, implement a more extensive but still streamlined prevention program, and implement an emergency response program.
- **Program Level 3:** Conduct a hazard assessment, document a management system, implement a prevention program that is basically identical to the OSHA PSM Standard, and implement an emergency response program.

Summary of Similarities and Differences between PSM and RMP

Although the PSM and RMP share the same goals, they are both similar and different. These similarities and differences were pointed out in the preceding text but to gain a more concise picture of these similarities and differences, the following section outlines them.

SIMILARITIES BETWEEN PSM AND RMP

- Process hazard analysis
- Emergency response guidelines
- Safety and compliance audits
- Training
- Incident investigation requirements
- Mechanical integrity requirements
- Standard operating procedures
- Process safety information
- Management of change
- Required employee participation
- Required hot work permits
- Contractor requirements

ITEMS FOUND ONLY IN PSM

- Trade secrets

ITEMS FOUND ONLY IN RMP

- Facility registration
- Management systems requirements
- Recordkeeping requirements
- Five-year accident history
- Worst-case release scenarios
- Regulatory audit requirements
- Analysis of off-site consequences
- Local emergency planning committee (LEPC) interface
- Risk management plan requirements
- Requirements for providing public information regarding a chemical release, for reporting incident information, and for emergency response drills (exercises)

The Bottom Line

According to the statute, EPA's Risk Management Program (RMP) regulation is to

provide, to the greatest extent practicable, for the prevention and detection of accidental releases of regulated substances and for response to such releases by the owners or operators of the sources of such releases. . . . As appropriate, such regulations shall cover the use, operation, repair, replacement, and maintenance of equipment to monitor, detect, inspect, and control such releases, including training of persons in the use and maintenance of such equipment and in the conduct of periodic inspections. The regulations shall include procedures and measures for emergency response after an accidental release of a regulated substance in order to protect human health and the environment. The regulations shall cover storage, as well as operations.

—CAA Section 112(r)(7)(B)(i)

If OSHA's Process Safety Management and the EPA's Risk Management Planning regulations work to prevent the ghosts of victims of any Bhopal-like incident from whispering "Too late. Too late," then these two regulations and their requirements will have more than amply demonstrated their real worth.

Notes

Risk management planning section adapted from F. R. Spellman's *Guide to Compliance for PSM/RMP*. Lancaster, Pa.: Technomic Publishing, 1997.

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BASIC AWARENESS BROCHURES FOR SPECIFIC SECTORS (APRIL 1998)

- EPA's Risk Management Program: How Does It Affect Chemical Distributors?*
- EPA's Risk Management Program: How Does It Affect Operators of Water Treatment Systems?*
- EPA's Risk Management Program: How Does It Affect Operators of Ammonia Refrigeration Systems?*
- EPA's Risk Management Program: How Does It Affect POTWs?*
- EPA's Risk Management Program: How Does It Affect Propane Retailers and Users?*
- EPA's Risk Management Program: How Does It Affect Chemical Warehouses?*

FREE SOFTWARE

- RMP*Comp: an electronic tool used to perform the off-site consequence analysis required under the Risk Management Program rule (currently available in draft form).
- Q&A database: a database of questions and answers related to the Clean Air Act (CAA) Section 112(r) and the Emergency Planning and Community Right-to-Know Act (EPCRA).

GUIDANCE DOCUMENTS

- Risk Management Plan Data Elements and Instructions*
- RMP Guidance for Implementing Agencies*
- CAA 112(r) Frequently Asked Questions* (currently 101 Q&As; more are being prepared)
- CAA 112(r) Offsite Consequence Analysis Guidance*
- Generic Guidance: CAA 112(r) RMP for Ammonia Refrigeration Facilities* (June 1996)

NON-EPA RMP PUBLICATIONS

- Publication 760, Model Risk Management Plan Guidance for Petroleum Refineries—Guidance for Complying with EPA's RMP Rule (40 CFR 68)*, 1st ed., August 1997 (American Petroleum Institute [API])
- Publication 761, Model Risk Management Plan Guidance for Exploration and Production Facilities—Guidance for Complying with EPA's RMP Rule (40 CFR 68)*, 1st ed., August 1997 (American Petroleum Institute [API])

A Compliance Guideline for EPA's Risk Management Program Rule (Chemical Manufacturers' Association [CMA])

Compliance Guidance and Model Risk Management Program for Water Treatment Plants (American Water Works Association Research Foundation [AWWARF])

FACT SHEETS

Funding Sources for Implementing the Risk Management Program (May 1998)

Modifications to the List of Regulated Substances (April 1998)

*Risk Management Program: RMP*Submit RMO*Info* (January 1998)

Risk Management Planning: Accidental Release Prevention; Final Rule

Chemical Accident Prevention and the Clean Air Act Amendments of 1990

Clean Air Act Section 112(r); Excerpts from the Statute

List of Substances for Accidental Release Prevention: CAA 112(r)

RMP products available from the CEPPPO Internet web page: www.epa.gov/ceppo.

CHAPTER 7

Chemical Hygiene Plan

The Occupational Safety and Health Administration's (OSHA's) Laboratory Standard requires laboratory employers to develop and implement a chemical hygiene plan (CHP). This plan must (1) set forth procedures, personal protective equipment (PPE), safety equipment, and safe work practices that will protect laboratory workers from the health hazards presented by hazardous chemicals used in the laboratory; and (2) keep exposures below the OSHA permissible exposure limits (PELs).

The CHP should include each of the following elements and indicate specific measures that the employer will take to ensure protection of its laboratory workers:

- Standard operating procedures (SOPs) relevant to employee health and safety for work with hazardous chemicals
- Chemical hazard control measures that the employer will implement to reduce exposures; that is, control measures such as engineering controls, protective equipment (administrative controls), and hygiene practices
- Laboratory ventilation and hoods will be maintained so that they function properly
- Employee information and training will be provided
- Circumstances under which particular lab operations require prior management approval
- Provisions for medical consultation and examination
- Designation of personnel responsible for implementing the CHP, including a Chemical Hygiene Officer (CHO) and/or a Chemical Hygiene Committee (CHC)
- Additional employee protection for work with chemicals that have a high degree of acute toxicity and chemicals of unknown toxicity (e.g., carcinogens, acutely toxic substances, etc.)
- Provisions for reviewing, evaluating, and updating (if required) at least annually

Chemical Hygiene Plan

OSHA requires managers of environmental laboratories where hazardous chemicals are used to develop a laboratory health and safety plan. The chemical hygiene plan can,

under certain conditions, take the place of the lab's health and safety plan. In order to do this the laboratory's CHP must be carefully crafted. We recommend this practice because a CHP is easier to implement, to maintain, and to update.

The question becomes: What is required to ensure that a facility's CHP meets all OSHA requirements or guidelines—so that it can stand alone as the lab's written safety and health program?

We answer this question in the following.

In order to stand alone as *the* written laboratory health and safety program, the CHP must include the following elements:

- Health and safety standard operating procedures (SOPs)
- Criteria for implementing control measures
- Requirement that laboratory hoods and other protective equipment (engineering controls) function properly
- Provisions for information and training for new and long-term employees
- Circumstances under which particular operations require prior management approval
- Provisions for medical consultations and examinations
- Designation of chemical hygiene officer/health and safety officer
- Additional protection provisions for work with particularly hazardous substances
- Fire protection and prevention
- Laboratory safety inspections
- Provisions for radioactive materials, infectious agents, and/or controlled substances

It is important to point out that the elements listed above are *suggested*; that is, they are only suggestions because the OSHA Laboratory Standard is a performance standard. A performance standard allows the employer “license” (a great deal of flexibility) in putting together a particular safety program or plan. Having said this, it is also important to point out that some lessons are learned through experience—such as, the ordeal of having the lab's CHP closely scrutinized during an OSHA audit. From such an experience, it is safe to say that if the reader satisfies the elements listed above, he or she will have little trouble with the regulators.

Chemical Hygiene Plan: An Example

Regarding safety and health compliance programs, it is relatively easy for someone to discuss or point out to someone else what is required to be accomplished. The purpose of this text is to do this but also to *show* exactly what is required. Thus, in this section a Chemical Hygiene Plan that has been used for several years and updated regularly is described in full. This particular plan is an excellent example of the type of written CHP that can be used in the environmental laboratory. It is an excellent plan because it has been tested, audited, and corrected (as needed).

=====

XYZ INDUSTRIES
CHEMICAL HYGIENE PLAN

CENTRAL ENVIRONMENTAL LABORATORY
and
SPECIAL PROJECTS LABORATORY (BIOASSAY)

=====

I. INTRODUCTION

XYZ Industries, a water-products chemical manufacturing industry, serves primarily the southeastern United States. Currently, one Central Environmental Laboratory performs laboratory services for water/wastewater treatment plant customers. Further, the Central Environmental Laboratory (CEL) also services analytical programs including phosphorus removal, municipal storm water management, and specialized metal and organic analyses.

The Occupational Safety and Health Administration's (OSHA's) regulation for "Occupational Exposures to Hazardous Chemicals in Laboratories," 29 CFR 1910.1450 (the standard), requires that each facility engaged in the laboratory use of hazardous chemicals develop and implement a written program known as a Chemical Hygiene Plan, which sets forth procedures, equipment, personal protective equipment, and safe work practices that will:

- protect employees from the health hazards presented by hazardous chemicals used in that particular workplace; and
- keep employee exposures to hazardous chemicals below the permissible exposure limits (PELs) specified in the standard.

Notice to all lab workers: All laboratory personnel are responsible for familiarizing themselves with XYZ's Chemical Hygiene Plan and adhering to it. Emphasis in the Chemical Hygiene Plan is placed first and foremost on protecting the employees. Moreover, failure to comply with this requirement is considered cause for disciplinary action. Copies of this written program will be available for review and reference by all employees in the following locations within the Central Environmental Laboratory:

1. Outside the Biochemical Oxygen Demand #126 section in the CEL "Right-to-Know" station.
2. CEL library.

The basic components of this program are:

1. Safety committee: responsibility
2. Definition of terms

3. Chemical inventory list
4. Basic rules and regulations
5. Material Safety Data Sheets (MSDSs)
6. Container labeling
7. Safe work practices
8. Hazardous material awareness, handling, and disposal
9. Employee training and information
10. Accident reporting procedure
11. Training records/documentation

II. SAFETY COMMITTEE

XYZ's Safety Division is the overall coordinator of safety programs and requirements for all departments. In addition, the Safety Division is responsible for organizing, stimulating, and guiding XYZ's safety program, as well as keeping up with changes in safety subject areas so as to provide knowledge and information, when required, that is current.

XYZ's Central Environmental Laboratory (CEL) shall designate in writing a Safety Officer, Assistant Safety Officer, Safety Technician, and Hazardous Waste Coordinator; these names are to be listed in appendix X of this program. These designated individuals are automatically members of the laboratory's safety committee.

A. Responsibilities

1. Safety Officer

The Safety Officer has the overall responsibility for optimizing safety training, conducting inspections, safety equipment acquisition, and updating safety information. If a problem arises, personnel may seek safety and health guidance from the Safety Officer, Assistant Safety Officer, or Safety Technicians. The Safety Officer must see to it that protective equipment is available and used appropriately. The Safety Officer is to make sure that periodic inspections (as specified) of emergency equipment are conducted; equipment such as fire extinguishers, safety showers, fire blanket, eye wash, and safety supplies are to be inspected. Further, the Safety Officer is to perform periodic inspections of the laboratory to uncover overlooked hazards, to ensure that lab personnel are following safety rules, and to remind workers to use safe work practices. Any violations of the safety rules will be reported immediately to the Safety Officer or Assistant Safety Officer. The Safety or Assistant Safety Officer will determine if the violation merits disciplinary action; if so, a formal report of the incident will be made in writing to the Chief of the Laboratory Division.

Other Responsibilities:

- a. Works with administrators and other employees to develop and implement appropriate chemical hygiene policies and safe work practices.

- b. Monitors procurement, use, and disposal of chemicals used in the laboratory.
 - c. Ensures that appropriate audits of safety equipment, emergency supplies, and first aid supplies are made and that any discrepancies are corrected immediately.
 - d. Develops safe work practices for new projects in the laboratory and ensure that they are practiced.
 - e. Knows the current legal requirements concerning regulated substances.
 - f. Seeks ways to improve the lab's chemical hygiene program.
2. Assistant Safety Officer Responsibilities
- a. Works with Safety Officer, administrators, and other employees to develop and implement appropriate chemical hygiene policies and safe work practices.
 - b. Assists Safety Officer in monitoring the procurement, use, and disposal of chemicals used in the laboratory.
 - c. Submits quarterly reports of activities and findings to the Safety Officer.
 - d. Coordinates and oversees the chemical hygiene policies with the Safety Officer and the Safety Division.
3. Safety Technicians' Responsibilities
- a. Makes monthly inspections of all equipment such as fire extinguishers, fire blankets, safety showers, and eyewash stations for proper operation. Submits inspection reports to the Safety Officer or Assistant Safety Officer.
 - b. Checks monthly to ensure that the emergency supplies are complete and reports any deficiencies to the Safety Officer or Assistant Safety Officer immediately. Emergency supplies are to include the following:
 - 1) First aid supplies
 - 2) Acid and base neutralizer powder
 - 3) Spill absorbent powder
 - 4) Mercury spill tamer kit with mercury suction collection bottle
 - 5) Emergency oxygen
 - 6) Fire blanket
 - 7) Dust pan
 - c. Ensures that protective equipment such as gloves, goggles, laboratory coats or aprons is properly used. Alerts the Safety Officer or Assistant Safety Officer of any infractions.
 - d. Reports to the Safety Officer or Assistant Safety Officer any safety violations and hazards observed.
 - e. Reviews MSDS inventory record at least once each quarter.
4. Hazardous Waste Coordinator Responsibilities
- a. Maintains records for the types and amounts of hazardous wastes generated.

- b. Coordinates with the Technical Services Division for the safe disposal of hazardous wastes by a qualified contractor.
 - c. Provides technical information to CEL employees regarding special disposal procedures.
 - d. Ensures that CEL employees are wearing the proper personal protective equipment when disposing of hazardous waste.
 - e. Ensures that storage containers for hazardous waste meets all OSHA, EPA, and DOT regulations.
5. CEL Building Coordinator's Responsibilities
- a. Works in concert with the Safety Officer to identify safety hazards and correct them.
 - b. Orders and arranges installation of safety equipment and correction of safety hazards.
 - c. Reports all safety hazards or unsafe work conditions that come to his or her attention to the Safety Officer or Assistant Safety Officer.

Note: When CEL safety and health issues need to be addressed and decisions made, the above-mentioned persons will function as the lab's safety committee to make recommendations to upper management as required.

III. DEFINITION OF TERMS

1. **Carcinogen:** a chemical is considered to be a carcinogen if:
 - a. It has been evaluated by the Internal Agency for Research on Cancer (IARC) and found to be a carcinogen or potential carcinogen; or
 - b. It is listed as a carcinogen or potential carcinogen in the *Annual Report on Carcinogens* published by the National Toxicology Program (NTP); or
 - c. It is regulated by OSHA as a carcinogen.
2. **Chemical:** any element, chemical compound, or mixture of elements and/or compounds.
3. **Chemical Exposure Limit List:** list of some common chemicals stored and used within the XYZ's Central Environmental Laboratory (CEL). The permissible exposure limit (PEL), threshold limit value (TLV), and immediately dangerous to life and health limit (IDLHL) are listed where applicable.
4. **Chemical manufacturer:** an employer with a workplace where chemical(s) are produced for use or distribution.
5. **Chemical name:** 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.

6. **Combustible liquid:** any liquid having a flashpoint at or above 100°F (37.8°C), but below 200°F (93.3°C), except any mixture having components with flashpoints of 200°F (93.3°C) or higher, the total volume of which make up 99 percent or more of the total volume of the mixture.
7. **Common name:** designation or identification such as a code, name, code number, trade name, brand, or generic name used to identify a chemical other than by its chemical name.
8. **Compressed gas:**
 - a. A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C); or
 - b. 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); or
 - c. A liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM Method D-323-72.
9. **Corrosive:** a chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact.
10. **Explosive:** a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.
11. **Exposure:** occurs when an employee, in the course of employment, is subjected to a hazardous chemical through any route of entry (inhalation, ingestion, skin contact), and includes potential for exposure.
12. **Flammable:** describes a chemical that falls into one of the following categories:
 - a. Aerosol, flammable: 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.
 - b. Gas, flammable: (1) a gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less; or (2) a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air more than 12 percent of volume, regardless of the lower limit.
 - c. Liquid, flammable: any liquid having a flashpoint below 100° F (37.8°C), except any mixture having components with flashpoints of 100° F (37.8°C) or higher, the total of which make up 99 percent of the total volume of the mixture.
 - d. Solid, flammable: a solid, other than a blasting agent or explosive as defined in Section 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.

13. **Flashpoint:** the minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite.
14. **Foreseeable emergency:** any potential occurrence such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment, which could result in an uncontrolled release of a hazardous chemical into the workplace.
15. **Hazard warning:** any symbols, pictures, or words, or combination thereof appearing on a label or other appropriate form of warning that convey the hazards of the chemical(s) in the container(s).
16. **Hazardous chemical:** any chemical that is a physical or health hazard.
17. **Health hazard:** 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 membrane.
18. **Irritant:** a chemical that is not corrosive but causes a reversible inflammatory effect on living tissue by chemical action at the site of contact.
19. **Label:** any written, printed, or graphic material displayed on or affixed to containers of hazardous chemicals.
20. **Laboratory:** a facility where the laboratory use of hazardous chemicals occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.
21. **Laboratory scale:** work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. Laboratory scale excludes those workplaces whose function is to produce commercial quantities of materials.
22. **Laboratory-type hood (enclosed bypass fume hood):** a device located in a laboratory that is an enclosure on five sides with a movable sash or fixed partial enclosure on the remaining side, constructed and maintained to draw air from the laboratory, and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.
23. **Laboratory use:** the handling or use of hazardous chemicals where all of the following conditions are met:
 - Chemical manipulations are performed on a laboratory scale
 - Multiple chemical procedures or chemicals are used
 - Procedures are not part of or simulate a production process

- Protective laboratory practices and equipment are available and used commonly
- 24. **Material Safety Data Sheet (MSDS):** written or printed material concerning a hazardous chemical, which is prepared in accordance with approved regulations.
- 25. **Mixture:** any combination of two or more chemicals if the combination is not, in whole or part, the result of a chemical reaction.
- 26. **Oxidizer:** a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, thereby causing fire either by itself or through the release of oxygen or other gases.
- 27. **Permissible exposure limit:** the maximum time-weighted average (TWA) concentration of a substance in air that an employee can be exposed to legally during an eight-hour shift.
- 28. **Physical hazard:** a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive.
- 29. **Pyrophoric:** a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.
- 30. **Reproductive toxins:** chemicals that affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis).
- 31. **Threshold limit value (TLV):** a term used by the American Conference of Governmental Industrial Hygienists to express the airborne concentration of a material to which nearly all workers can be exposed day after day without adverse effects.
- 32. **Unstable (reactive):** a chemical that in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or become self-reactive under conditions of shock, pressure, or temperature.
- 33. **Water-reactive:** a chemical that reacts with water to release a substance that is either flammable or presents a health hazard.
- 34. **Work area:** a room or defined space in a workplace where hazardous chemicals are produced or used, and where employees are present.

IV. CHEMICAL INVENTORY

The chemical inventory sheet (along with MSDSs) in CEL's Worker Right-to-Know Book lists all the chemicals currently stored or in use. Although it is not stated that all chemicals are hazardous, all chemicals must be handled with caution.

Information regarding the potential hazard of a chemical can be found in the Material Safety Data Sheet (MSDS) for the chemical. Other chemical information sources such as the *Condensed Chemical Dictionary*, *Merck Index*, *Hazards in the Chemical Laboratory Manual*, and the *Annual Report of Carcinogens* must also be consulted if other information is required. Consult the Safety Officer or Assistant Safety Officer if information concerning a chemical cannot be found.

V. CHEMICAL HYGIENE AND SAFETY PLAN

A. General Rules

1. Working alone

Working alone in the laboratory will not be permitted when dealing with hazardous and corrosive chemicals or when the work involves a potentially dangerous procedure. Some areas of work that must be avoided when working alone are:

- a. Analysis involving highly flammable gas such as acetylene, nitrous oxide, methane, or propane gas.
- b. Analysis involving possible poisoning from toxic gas such as the analysis of cyanide or chlorine standard preparation involving bottled chlorine gas.
- c. Preparation of acid or base solutions that involve large amounts of the concentrated solution.

2. Personal apparel

- a. Shoes must be worn at all times in the laboratory. Sandals, perforated shoes, or open-toed shoes will not be worn in the laboratory.
- b. Shorts or torn clothing will not be allowed in laboratories. *Use of full-length long sleeve lab coat is mandatory.*

3. Personal housekeeping

All work areas must be kept clean and uncluttered, with chemicals and equipment properly labeled and stored. The work area must be cleaned upon completion of a test or at the end of each working day.

4. Horseplay

Avoid practical jokes or other behavior that might confuse, startle, or distract other workers, especially in the presence of hazardous chemicals or when a potentially dangerous procedure is involved.

5. Eating/drinking/smoking/applying cosmetics

Eating and applying cosmetics in areas where potentially hazardous chemicals are present will not be allowed. Eating, drinking, and applying cosmetics in areas where chemicals are present is a potentially hazardous situation because of the possibility of contaminating the food, drink, or cosmetics with unknown substances. Eating should be restricted to designated break rooms and administrative areas. Drinking will be allowed on a limited basis within the laboratory. Employees may drink soda or coffee at desk areas, as long as hazardous chemicals are not present and/or not handled. Further, employees must use a closed container such as a soda can or covered cup with straw when drinking within the laboratory. However, food, drink, and cosmetics are not allowed on laboratory bench tops. Application of cosmetics is allowed in the administrative area and the restrooms. Smoking in any part of the laboratory (including stockrooms) is strictly prohibited.

6. Unattended operations

There will not be any unattended procedures involving hazardous substances or dangerous steps taken without prior approval from the Safety

Officer. Appropriate warning signs outside areas where hazardous procedures are in progress must be clearly posted.

All utility devices such as cooling water (secure connections), gases, etc., must be checked and secured (e.g., compressed gas cylinders 150 pounds and under are affixed to wall/floor or bench).

7. Glassware

Dispose of all broken or cracked glassware and used syringe needles in proper broken glass and sharps disposal receptacles immediately. Chipped glassware may still be used if it can be fire-polished to eliminate the sharp edges.

Use caution when making rubber-to-glass connections. Support lengths of glass tubing while they are being inserted into rubber. Fire-polish ends of glass tubing until smooth. Use a lubricant such as water—*never use grease or oil*. Use gloves when making such connections and hold tubing as close as possible to the end being inserted to prevent bending and breaking. Never try to force rubber tubing or stoppers from glassware; cut rubber as necessary to remove.

8. Disposal of chemicals

No chemical or substance (except water/wastewater between pH 2 and 12.5) should ever be disposed of down the sink/drain without first consulting the Hazardous Waste Coordinator or Safety Officer and reading the MSDS.

B. Laboratory Standard Operating Procedures (SOPs)

Every standard operating procedure in the laboratory requires precautionary measures that must be taken in order to execute each procedure safely. The operator must read and understand the procedure thoroughly (especially procedures involving toxic substances) before proceeding. Any questions regarding the safe execution of the procedure *must* be addressed before attempting to execute the procedure. Adherence to all safety work practices outlined below is a *must* to assure safety in the laboratory.

C. Use of Protective Equipment and Apparel

1. Hoods and ventilation

a. Any operation that might result in the release of toxic chemical vapor or dust must be performed under a properly functioning hood. Use a hood or other form of local ventilation when working with any appreciably volatile substances.

b. Confirm adequate hood performance before each use.

c. Keep the hood *on* at all times when it is not in active use if toxic substances are stored in it. However, acid, caustic, and flammable cabinets should be used as much as possible for storage.

d. Keep materials stored in hoods to a minimum and do not allow them to block air flow.

e. When a hood is not in use, keep the sash in the down position.

Confirm adequate hood performance before each use by referring to the air flow monitor on the side of the hood. If the hood does not have a

built-in airflow monitor, use a hood airflow measuring device such as a velometer (available in the CEL and XYZ Safety Office). Confirm hood performance with the sash in the down position. Hood face velocity must not be excessively turbulent. Typically, a hood face velocity of 60–100 linear feet per minute is adequate. Also check to see if the hood inspection sticker is current (inspected within the last three months). Do not use a malfunctioning hood and report any deficiency immediately to the Safety Officer or a supervisor.

2. Eye protection

The objective of the lab's eye protection policy is to protect the eyes of CEL employees and CEL visitors. Moreover, the policy pertains to all XYZ employees, vendor representatives (demonstrating, modifying, or repairing analytical or analytically related equipment in the CEL), and all CEL personnel who closely observe analytical activities.

All personnel in the CEL must wear CEL-approved protective eyewear whenever they are involved in the following activities:

- Any aspect of analyses except data manipulations
- Labware preparation
- Solution and sample preparation
- Sample handling
- Any close observation of an analytical process that requires protective eyewear

There are two general categories of lab situations in which different levels of eye protection are required.

- (1) **General Protection:** This is characterized by the involvement in analyses or support activities that require the use of materials, samples, or solutions that are not known to result in bodily damage upon contact but could be harmful if eye contact was made. These materials are further characterized as having a pH >2.0 and <12.0 , and a normality <2.0 .
- (2) **Enhanced Protection:** This is a situation in which the analysis or support activity involves the use of a distinctly hazardous material. These materials are characterized with a pH <2.0 or >12.0 , and/or a normality >2.0 . This level of protection is also required when the nature of materials is unknown.

The following types of eyewear are approved for use according to the applicable protection category:

General Protection:

- Prescription glasses with shatterproof lenses, equipped with side shields. The side shields will be provided by the CEL.
- General safety glasses that comply with the safety standard ANSI Z87.1-1989. These are supplied by the CEL.
- General-purpose face shields. These are also provided by the CEL.

Enhanced Protection:

- Safety goggles, chemical splash- and impact-resistant, indirectly vented; in compliance with safety standard ANSI Z87.1-1989. These are supplied by the CEL.

When contact lenses are to be worn in the laboratory, protective chemical goggles providing protection from flying objects and chemical splash must be worn at all times when performing any type of analytical procedure, with the exception of data manipulations. Any CEL personnel wearing contact lenses, and engaged in any aspect of analysis, must notify their supervisor of this vision correction method prior to analytical activity.

Contact lenses do not provide protection. The capillary space between the contact lenses and the cornea may trap any material present on the surface of the eye. Corrosive chemicals trapped in this space cannot be washed off the surface of the cornea. If the chemical in the eye is painful or the contact lens is displaced, muscle spasms will make it very difficult, if not impossible, to remove the lens.

Certain analytical areas and functions are currently considered not hazardous to eyes. An attempt will be made to accommodate these areas and associated personnel by exempting them from compliance with this policy as long as no obvious eye hazard exists. These areas include the following:

- Microbiology rooms
- Operation of a computer associated with an analytical instrument

The success of the exemptions listed above depends on personnel and their ability to routinely remember to wear eye protection in the other areas and for other functions that require the protection.

3. Body protection

Body-protecting garments such as long-length, long-sleeved laboratory coats must be worn at all times when performing any type of analytical procedure in the laboratory. Laboratory aprons can be worn under unusual circumstances, for example when the air conditioning is out of service. Laboratory aprons can also be worn over laboratory coats for added protection. Body protection will protect the body and clothing from chemical spills such as acids and bases.

4. Hand protection (rubber or latex gloves)

The danger of contact with corrosive or toxic chemicals must be minimized by the use of protective latex or rubber gloves. The following are guidelines to follow when selecting gloves:

- a. **Long length.** Gloves are heavy duty, usually green or black, made from a nitrile base, have a 22 mil thickness, and are approximately 18–24 inches long. These gloves are used for working in acid baths because protection is provided to the upper arms and

the gloves are acid resistant. Due to the thickness of the glove, better protection against rips and tears that may be caused by broken glass is provided.

Note: These gloves can be used when working in any acid bath at *any* concentration. Further, these are the only gloves acceptable for working in an acid bath.

- b. **Playtex gloves.** A medium-weight glove. The gloves are generally blue or yellow, have a thickness of 25 mil or greater, are made of natural latex, acid resistant, and resistant to rips and tears caused by broken glass. Since Playtex gloves are shorter than the long-length gloves, Playtex gloves are not acceptable for use in acid baths. Use Playtex gloves for the following:
 - Working with *any* acid *not* in an acid bath
 - Washing or rinsing of any glassware
 - Loading and unloading the glassware washers
 - Handling any soaps
- c. **Common use latex/nitrile gloves.** Latex gloves are generally opaque-white in color. Nitrile gloves may come in a variety of colors (blue, green, etc.). Both these types of gloves are only 4–9 mil thick and only about 9.5 inches long. This type of glove is also acid permeable. Due to thinness, lack of arm protection, and acid permeability, these gloves would not protect the hand or arm against broken glass or chemical spills. These gloves are intended to be used when handling biological samples, such as raw wastewater or biosolids.

These gloves are not acceptable for use in the glassware section of the CEL.

Gloves providing thermal insulation must be used at all times when transferring objects in and out of an oven or furnace.

The type of glove worn should be appropriate to the analysis being performed; when in doubt, consult the Safety Officer.

5. Chemical storage and handling

Many chemical substances used in a laboratory are toxic to humans when ingested or inhaled. Precautions must be taken with these substances to keep them out of the mouth, nose, eyes, and the skin. It is important to wear protective clothing, gloves, and safety glasses when handling toxic or corrosive chemicals.

The following are specific laboratory rules and precautions that must be followed:

A. Chemical Storage

1. Never place beakers or unstoppered (uncapped) vessels containing chemicals in a refrigerator. Volatile-containing samples should be stored in a special refrigerator designed to accommodate such materials, where available. These are

explosion-proof refrigerators especially suited to this application.

2. Label all chemical containers correctly and clearly. The following information must be included in the chemical label:
 - a. Date the chemical was prepared with initial of analyst who prepared the chemical.
 - b. Date the chemical was received.
 - c. Date the chemical was opened and expiration date.
 - d. Appropriate hazard warning such as corrosive, flammable, carcinogen, or oxidizer (where applicable).
3. Store acids and bases separately in well-ventilated areas and away from volatile organics and oxidizable materials. Do not store strong acids or bases on high shelves.
4. Store large reagent containers in the vented cabinets under the hoods. Ensure that flammable materials are stored in the flammable cabinets. Make sure that all containers used in the preparation of reagents or containers used to hold small amounts of reagents for short periods of time are clearly labeled.
5. All cyanide (CN-) compounds, barbituric acid and other regulated substances must be kept locked and accessible only to designated supervisors. Records must be kept of the usage and must contain the following information:
 - a. Identity and amount of chemical taken.
 - b. Date the chemical was taken.
 - c. Initial of the analyst using the chemical.
 - d. Intended use of the chemical (type of analysis).

B. Chemical Handling

1. Use fume hoods for all operations involving poisonous or offensive gases or fumes, as well as for operations involving highly flammable or potentially explosive materials.
2. Never heat an organic solvent in an open vessel over an open flame; keep open containers of organic solvents away from open flames or sources of sparks.
3. Avoid pointing the mouth of a vessel being heated towards any person, including you.
4. Never add anything to a concentrated acid, base, or strong oxidant; instead, add the acid, base or oxidant slowly and cautiously to the other ingredients, preferably no faster than it is consumed by reaction.
5. Never add solids (boiling chips, charcoal, etc.) to a hot liquid, as the result may be violent boiling if the liquid happens to be superheated. Perform such additions when the liquid is still at room temperature.

6. Never pipette anything by mouth. Use an automatic pipettor or a conventional pipette with a rubber bulb.
7. Never pour anything back into a reagent bottle. Consult the Hazardous Waste Coordinator for the proper disposal of unused or contaminated chemical.
8. Prevent accidents such as splashes and container spills. Use a funnel if pouring strong acids, bases or oxidants into a narrow-mouth vessel.
9. Wipe up small spills and bottle rings *immediately*. A large spill should be handled as indicated in Section 6, "Chemical Spills."
10. Do not flush cyanide compounds down a drain because of the danger of contact with acids flushed down somewhere else and the consequent evolution of toxic hydrogen cyanide gas.

Note: Other chemicals due to their high toxicity must be handled with caution. For information regarding the hazard that the chemical might pose, consult the Material Safety Data Sheet (MSDS) or other chemical reference materials discussed in this program. All necessary precautions outlined, such as the use of protective goggles, gloves, body protection, and fume hood must be followed when handling the chemical. Consult the Safety Officer or Assistant Safety Officer if further assistance is needed. Some examples of these chemicals are:

- Concentrated acids (hydrochloric, sulfuric, nitric, chromic, phosphoric, glacial acetic)
- Concentrated bases (sodium, potassium, ammonium hydroxides)
- Cyanide salts and phenols
- Mercury and mercuric salts
- Heavy metal compounds (Ba, Be, Pb, Cu, Ag, Zn, Cd, Cr, Ni, As, and others)
- Oxidizing salts (AgNO_3 , chromates) (potassium dichromates)
- Benzene

C. Microbiological Hazards

Potential dangers associated with this type of hazard involves hand-mouth contact while handling contaminated samples or laboratory equipment. Some safety rules that must be used are as follows:

1. Always use protective gloves when handling microbiological standards and samples.
2. Never pipette anything by mouth. Use an automatic pipettor or a conventional pipette with a rubber bulb.
3. Keep contaminated items (cultures, serological discards, etc.) in a separate waste container before sterilizing. Do *not* throw these in with the routine trash.

4. Sterilize or disinfect contaminated materials (cultures, used glassware, serological discards, etc.) by autoclaving before throwing them away or processing for reuse. Use a germicidal soap and hot water, or an autoclave, as appropriate for the type of analysis involved. All cell culture glassware is to be autoclaved.
 5. Quickly clean up any spillage. Disinfect the area with bactericide, alcohol, or other type of disinfectant.
 6. Frequently disinfect working surfaces with bactericide or germicide. Disinfect hands with dilute germicidal soap.
6. Chemical Spills
- a. Small chemical spills and leaks must be cleaned up immediately to prevent a potential hazardous situation.
 - Spill Tamer Kits are provided and located in the CEL as follows:
 - Mercury and Acid Spill Tamer kits located outside Wet Chemistry Lab; these kits contain the following items:
 - a. Neutralizer solution for acids
 - b. Neutralizer solution for alkalies
 - c. Mercury Spill Tamer solution
 - d. Mercury collector bottle
 - e. Spill absorbent powder
 - f. Emergency oxygen
 - Acid Spill Tamer Kit located between Metals Prep Lab and Metals ICP-AA Lab.
 - b. Chemical spill control: spill control measures for acid or base solutions:
 - 1) Concentrated acid spills should be cleaned up as follows: Wearing gloves and goggles, add dry acid neutralizer to the liquid spill in excess. Cover all the affected areas repeatedly until all liquid is absorbed. Sweep/shovel the neutralized waste into a trash container. Wash down the cleaned area with copious amounts of water. Neutralize further if necessary, using sodium bicarbonate (baking soda) or commercial neutralizer. Sweep the neutralized wastewater from the spill into the floor drain or use absorbent toweling. It is important to neutralize the acid (or base) rather than trying to relocate it prior to clean-up.
 - 2) Solutions should be contained and absorbed using the Spill Tamer Absorbent from the Spill Tamer Kit.
 - 3) Add dry neutralizer for acids or neutralizer for alkalies until all reaction stops.
 - 4) Sweep up the absorbent and dispose of properly. Consult the Safety Officer or Assistant Safety Officer for proper disposal procedure.
 - 5) Rinse the spill area thoroughly with water.
 - 6) Spills adjacent to a sink that can be washed into the sink safely should be handled in this manner. The area can be neutralized

using cold water and dry neutralizer for acids or neutralizer for alkalies, or pH 6.9 solution.

c. Dry alkali spills

- 1) Dry, solid material should be swept together, using the dustpan and brush from the Spill Tamer Kit.
- 2) Dissolve the alkali in a beaker of water.
- 3) Flush the alkaline solution into the sink drain with generous amounts of cold water.
- 4) Rinse the spill area thoroughly with water, pH 6.9 solution, then water.

d. Mercury spill

Any spill of mercury from a broken thermometer, manometer, etc., can create a serious toxicity problem if cleanup is not handled properly. The mercury will continue to vaporize, causing a chronic exposure situation. Mercury poisoning can occur from chronic exposures as well as from a one-time exposure to large quantities of the metal.

- 1) Notify other lab personnel of the spill.
- 2) Wearing rubber gloves, use the Mercury Spill Kit located in the Spill Tamer Kit.
- 3) Collect as much mercury as possible, using the suction collection bottle.
- 4) Sprinkle the area with Mercury Tamer, sweeping to mix the Tamer thoroughly with the remaining mercury. Sweep this mixture up and collect the mixture into a glass or plastic container that can be sealed.
- 5) Sprinkle the area again with Mercury Tamer, leaving it on for several days if possible. (The sulfur in the Mercury Tamer will deactivate the mercury).
- 6) Dispose of the mercury collection bottle, and other equipment used in contact with the spill, by approved mercury disposal—i.e., contain equipment in secure, labeled bag and place in the solid mercury waste disposal drum (Hazardous Waste Storage Area). Dispose of in the solid mercury waste drum.

7. First Aid

a. First aid kits for minor injuries are located in the following areas in the CEL:

- Glassware prep area
- Biochemical Oxygen Demand Lab
- Metals prep lab

b. Burn emergency kits for minor burns are located in the following areas in the CEL:

- Total solids lab
- Metals prep lab

c. Chemical burns

Emergency burn kits for acid and alkali burns are located in the following areas of the CEL:

- Chemical Oxygen Demand Lab
 - Wet chemistry lab
 - Auto-nutrients lab
 - Total solids lab
 - Metals prep lab
 - Metals lab
- d. Emergency procedure for chemical burns
- 1) Flush the affected area with copious amounts of water, using the emergency shower as needed for at least five minutes. Depending on the situation, get medical care immediately.
 - 2) If first aid directions for burns caused by specific chemicals are available, follow these directions, after the initial flushing with water. First aid directions can usually be found by referring to the Material Safety Data Sheet.
 - 3) DO NOT use oils, fats, salves, or ointments that could assist skin absorption.

e. Chemical poisoning

Chemical poisoning can result from inhalation, ingestion, or absorption through the skin of a toxic chemical. If you suspect that you or any of your fellow employees have been exposed to any type of chemical poisoning, get help immediately. Proceed as follows:

Determine the source of the poison. It is possible that the whole area might be contaminated with poisonous gas or chemical. If it is determined that the whole area is contaminated, notify all other personnel and have the area evacuated. Secure the contaminated area. Call the poison control center and describe the situation. Do not attempt to enter the area unless you are wearing the proper personal protective equipment and breathing apparatus.

1) Cyanide poisoning/inhalation of poison

Cyanide poisoning can result from ingestion, inhalation, or absorption through the skin.

Cyanide can be found in the following forms: inorganic compound sodium cyanide (NaCN), hydrogen cyanide (HCN; a toxic gas formed from the acidification of an inorganic cyanide compound), or an organic compound classified as a nitrile.

Toxic effects appear immediately with large doses; lesser doses cause dizziness, headaches, or vomiting. Symptoms include cherry-red skin color; rapid breathing, then irregular breathing; collapse; heavy sweating; and convulsions. Rapid attention and treatment is *mandatory*; otherwise death can occur. Because of this, whenever cyanide is being used, notify your supervisor *and* another technician so that help will be rapidly available if needed.

First aid procedures for cyanide poisoning:

1. Move the victim to fresh air.

2. Prevent shock by keeping the victim warm.
 3. Apply artificial resuscitation if the victim is not breathing. For personal safety do not perform a mouth-to-mouth resuscitation but instead, use a bag valve mask to revive the victim.
 4. Break an amyl nitrite capsule in a gauze pad and hold below victim's nose at chin level for 15–30 seconds out of each minute. Do not administer more than 5 capsules.
 5. If the victim has difficulty in breathing, administer emergency oxygen.
- 2) Ingestion of chemical solutions or poisons
1. Immediately notify another lab technician of the accident and type of material ingested. Obtain medical attention immediately.
 2. Do not induce vomiting if the solution swallowed was a strong base (alkali), strong acid, cyanide, strychnine, gasoline, kerosene, any hydrocarbon, or if the victim is having convulsions. Do not give liquids to an unconscious person.
 3. For strong acids or bases, give the victim a glass of milk or large amounts of water.
 4. Do not give oils, fats, or alcohol unless advised by a physician.
 5. Prevent shock by keeping the victim warm.

VI. MATERIAL SAFETY DATA SHEET (MSDS)

The Material Safety Data Sheets (MSDSs) are a set of individual data sheets providing related safety information for each hazardous chemical utilized or produced at the work centers. Material Safety Data Sheets are filed in each work center's "Right-to-Know" book. The "Right-to-Know" books for the CEL are located at the front entrance to the lab and outside the biochemical oxygen demand section.

MSDSs are provided to work centers by Procurement and the Safety Division any time manufacturers forward new copies or new editions. Work center supervisors are responsible for ensuring that MSDSs are current and available at all times for chemicals at their work center and that chemicals are not used unless this information is available, or familiarity with the chemical is established. Whenever MSDSs are added or deleted, the index of chemicals must be updated.

The Material Safety Data Sheets should contain the following information:

1. Identity of the hazardous chemical.
2. Identity of hazardous ingredients in a hazardous chemical mixture.
3. Chemical and physical characteristics of the hazardous chemical.
4. Chemical and physical hazards of the hazardous chemical.
5. Acute and chronic health hazards, including signs and symptoms of exposure and medical conditions that are generally aggravated by exposure to the hazardous chemical.
6. Primary route of entry.

7. Personal exposure limits in terms of maximum duration and concentration.
8. Protective measures and special precautions.
9. Emergency procedures and first aid procedures.
10. Date of preparation of the Material Safety Data Sheet.
11. Identification of person or agency responsible for the information contained on the Material Safety Data Sheet.

The Material Safety Data Sheets shall not contain any blank spaces. Not applicable or unknown information should be indicated as such.

All chemicals used in the laboratory facility are purchased chemicals. All MSDSs are supplied by the chemical manufacturer. Information on the MSDS must be complete and accurate. If the information on the MSDS is not complete or additional information is required, the Safety Officer must be notified before any further use of the chemical. The Safety Officer or Assistant Safety Officer will then contact the chemical manufacturer and request the missing information.

Other information resources are available in the CEL. These resources are located in the CEL library and are identified in the following:

1. *Condensed Chemical Dictionary*
2. *Compendium of Safety Data Sheets*
3. *Hazards in the Chemical Laboratory*
4. *Annual Report on Carcinogens*
5. *Research and Industrial Chemicals*
6. *First Aid and Personal Safety*
7. *First Aid Manual for Chemical Accidents*

For any chemical that exists in the CEL without any available MSDS, the above-mentioned references must be consulted to clearly identify the hazard of the chemical, before it is used. If information cannot be obtained, notify the Safety Officer. The chemical will be treated as hazardous and all necessary safety precautions will be taken. If an MSDS cannot be obtained on a chemical and the MSDS is needed for disposal methods or use, the Safety Division will research the chemical and produce a generic MSDS for the chemical. The CEL Safety Technician will be responsible for receiving, dating, and filing all laboratory MSDSs.

VII. CONTAINER LABELING

Chemical container labeling is the primary initial source of warning for employees. This requirement is considered one of the most important sections of this program in ensuring the overall effectiveness of the Chemical Hygiene Plan.

As discussed previously, chemicals used in the CEL are purchased chemicals. Thus, proper labeling of all these chemicals is the responsibility of the chemical manufacturer. Any chemical delivered to the CEL will be inspected upon receipt for proper labeling and completeness of information (MSDS included). If any chemical is not properly labeled and is not accompanied by the MSDS, the delivery will be rejected or sent back to source of delivery.

The Safety Officer or Safety Technician will oversee this chemical delivery process. CEL personnel who have completed HM-181/126-F training and attended half-day safety orientation training may take delivery of chemicals. CEL personnel receiving chemicals need to ensure that the following information appears on all incoming chemicals:

- The identity of the chemical
- Appropriate hazard warning
- The name of the chemical manufacturer
- The chemical label is in good condition and readable
- The chemical container is in good condition
- Shipping papers are in order

If any discrepancy is found on the chemical labeling, packaging, or shipping papers, CEL personnel are not to take delivery.

All other small containers or bottles stored in the CEL work area or countertop *must* be clearly labeled with the applicable information and appropriate hazard warning. If a reagent contains several hazardous materials, the name of the reagent must be clearly labeled on the container. The CEL Safety Officer, Technician, or Section Leader will be responsible for ensuring that this procedure is followed.

VIII. HAZARDOUS MATERIAL AWARENESS, HANDLING AND DISPOSAL

A. Administration

The aim of appropriate handling and proper disposal of hazardous materials is to ensure minimal harm to people, as well as to the environment. Hazardous waste abatement minimizes the potential for exposure to terrestrial and aquatic life, and it minimizes the cost of clean-up and disposal activities to XYZ. Awareness is one of the key factors in minimizing exposure to hazardous chemicals. Therefore, all CEL personnel are required to attend half-day Safety Orientation, HM-181/126-F, and Chemical Spill Emergency Response Training.

The Hazardous Waste Coordinator maintains records of types and amounts of hazardous wastes generated and coordinates with the Technical Services Division for the safe disposal of wastes by qualified hazardous waste disposal professionals.

B. Identification of the Waste

Each employee must be familiar with the variety of hazardous materials they might come into contact with in the CEL. For every analytical procedure, one or maybe all of the chemicals involved might be hazardous. Any chemical, even if it poses minimum threat or harm, when not handled safely or correctly can cause severe health damage and/or death.

When performing any analytical test, the following procedures must be observed:

1. Familiarize yourself with all the chemicals involved.
2. If information is needed concerning the nature of the chemicals, the employee must consult the Material Safety Data Sheet (MSDS) or other available reference manual.

3. Consult the Safety Officer or Hazardous Waste Coordinator if necessary.
4. Follow the proper use of protective equipment described in Section V of this program.
5. If the chemical requires special disposal procedures, consult the Hazardous Waste Coordinator.
6. Maintain familiarity with the chemicals, as the test may be repeated, or for future reference.

C. Minimizing Hazardous Waste

Minimizing the potential for exposure of humans to hazardous wastes is accomplished by minimizing the wastes. The volumes of hazardous wastes generated are dependent on the type and number of analyses. Due to these variables, the rate at which waste will accumulate fluctuates.

Constant monitoring of the amount of wastes that are generated in each laboratory section is essential to minimize the waste in the work area. A hazardous waste log book will be established and will contain the following information:

1. Identification and category of the waste. For example, list a waste as cyanide, mercury, acid, and so forth. If the waste contains more than one type of chemical, list all known components of the waste.
2. Amount of waste disposed of.
3. Hazard class (e.g., flammable, corrosive, caustic, acid, or suspected carcinogen).
4. Date the waste was placed in the drum.
5. Initial of the analyst who placed the waste into the drum.

In many cases the hazardous nature of the chemical is increased when the chemical is mixed with another type of chemical, especially when the chemicals are incompatible. To avoid this situation, chemical waste generated in the CEL will be segregated by type (e.g., acid waste, caustic waste, mercury waste, cyanide waste, and phenol waste).

The Hazardous Waste Coordinator will be in charge of maintaining all hazardous waste log books in the CEL. The hazardous waste log book will be kept in the hazardous waste storage area. A copy of the log book shall also be kept in the administrative area of the CEL.

D. Handling and Disposal

1. Handling

Proper handling of chemical waste generated in each lab section will be the responsibility of the analyst at the time the waste is generated. The analyst may dispose of the waste in the hazardous waste drums at any time; however, the analyst must be authorized to enter the hazardous waste storage area and the two-person rule must be used. The analyst will enter the appropriate information regarding the waste in the hazardous waste log book.

2. Disposal

Containers to be used for storing chemical waste must be the approved type that will not leak or corrode; they must meet compliance requirements

of DOT, OSHA, and EPA. Currently, waste is stored in approved drums that are in overpacks to provide double protection. If the waste generated is an unused portion of the chemical, the chemical must be stored in the original container until it is ready for disposal. Consult the Hazardous Waste Coordinator if assistance is needed. All containers used for storing waste must be labeled for their contents.

Hazardous waste containers that will be stored outside must be protected in such a manner as to prevent the contents from freezing because of the possible danger of the container breaking or splitting when the contents expand. Because there are no electrical outlets in the hazardous waste storage area, the overpacks are wrapped with solar blankets when temperatures drop.

Care must be taken by the employee to use common laboratory safety procedures when handling hazardous materials.

Always be prepared for emergency spills or splattering. Wear appropriate protective equipment. Moreover, when disposing of chemicals wear the following safety equipment:

- goggles
- lab coat
- Playtex gloves
- half-mask respirator with appropriate cartridges

Waste will be moved from the general laboratory work area to a central waste storage area at regular intervals to minimize volumes of hazardous materials accumulating in the laboratory. EPA's RCRA regulations state that the waste has to be removed 180 days from the date that the drum was started.

When sufficient quantities of hazardous materials have accumulated, a contractor will be employed by XYZ to remove the wastes from XYZ property.

The following is a list of hazardous wastes generated by the CEL that will be subject to strict inventory control and will require special disposal procedures.

- Phenol
- Cyanide salts
- Pyridine
- Mercury and compounds
- Highly concentrated acids and bases
- Highly concentrated metal compounds

Every time any of these chemicals is disposed of, the amount and identity of the waste *must* be entered into the hazardous waste log book. The hazardous waste log book will be located in the hazardous waste storage area and a copy will be maintained in the administrative area of the CEL. The Hazardous Waste Coordinator is responsible for maintaining the log book that is kept in the administrative area and for ensuring that employees are logging in their hazardous waste.

IX. FUME HOOD MANAGEMENT

A. General Information

Fume hoods and other associated protective equipment should be maintained in satisfactory operating condition at all times. Monitoring of performance and any scheduled preventive maintenance should be done in accordance with the manufacturer's suggested guidance. The OSHA Laboratory Standard states that fume hoods need to have a hood velocity of 60 to 100 linear feet per minute to be considered as adequate. In order to ensure that lab fume hoods continue to meet this standard, the Safety Division performs quarterly fume hood inspections. Moreover, during each inspection fume hood velocity checked. For each hood inspected an individual inspection sheet is used and all entries resulting from the inspection must be made there.

Hoods should also be closed at all times except when work is being accomplished or adjustments need to be made. To prevent restriction of air flow, materials stored in the hood should be kept to a minimum and should not block vents or air flow. If at any time an employee feels that the fume hood is not functioning properly, he or she should notify the Safety Officer or the Building Coordinator at once.

X. EMPLOYEE TRAINING AND INFORMATION: HAZARD AWARENESS

A. General Information

It will be the responsibility of the Safety Officer/Safety Division to inform employees of the hazards that they may be exposed to in the workplace. The primary goal of the Chemical Hygiene Plan is to protect employees from hazards through an extensive training program that will provide the employee the necessary tools required to minimize the risk of exposure in the laboratory.

B. Training and Information Program

In order for employees to be properly informed about hazardous materials in the workplace or specific work area, a training and information program (safety meeting) will be conducted on a quarterly basis. Discussion will include the requirements of the Chemical Hygiene Plan and specific problem areas (if any), as well as suggestions from all employees to improve the safety program of the laboratory.

The Safety Officer and/or Assistant Safety Officer will coordinate safety (training) meetings for the laboratory.

C. Key Provisions of Training

1. The requirements of the Chemical Hygiene Plan, its importance, and its primary goals shall be transmitted to all employees.
2. Information on operations of all work areas where an employee may be exposed to hazardous materials will be discussed in detail. Proper handling and precautionary measures that must be taken to abate the hazard shall be emphasized.
3. The employees shall be informed of the location of the hazard communication materials such as the Material Safety Data Sheets, Compendium

of Safety Data Sheets, other safety references, and emergency safety supplies.

4. Location and lists of hazardous materials that the CEL generates shall be made available to all employees.
5. Methods and observations to detect the presence of a hazardous material.
6. Use of proper protective equipment.
7. In the event that a new hazardous material is introduced to the workplace, information about the material shall be immediately transmitted to all employees who will be working with that material.
8. Ensure that all lab employees are given training on emergency and evacuation procedures.

D. New Employee Training

All new CEL employees shall attend General Safety Orientation Training given by the Safety Division every three months. While waiting for New Employee Safety Orientation training, all new employees will receive fundamental safety training that will allow them to start work in the CEL. The new employee shall be indoctrinated on OSHA's Hazard Communication and its Laboratory Standards. Each employee will be informed of his or her role and responsibilities within the program. The employee will be required to sign a form acknowledging that he or she has been informed of the existence of XYZ's Chemical Hygiene Plan. A record of the employee's acknowledgment shall be kept in the laboratory's training file, maintained by the Safety Division.

All new employees must attend the District's New Employee Safety Orientation. Laboratory employees are required to attend the first four hours of the eight-hour orientation session.

E. General Safety Training for All CEL Employees

All CEL employees shall be trained on the following laboratory safety procedures on a continuing basis. All safety training shall be documented.

1. Emergency evacuation
2. Use of PPE
3. Use of fume hoods
4. Use of safety eyewash/shower
5. Use of fire blanket
6. Use of emergency oxygen/respirators
7. Emergency response procedures for acid or caustic spills, inhalation or ingestion of poison, medical emergencies, and fire or explosion
8. Use of different types of fire extinguishers
9. Use of the MSDS and other safety reference materials

F. Safety Training Videos

Applicable safety films are available to be shown to CEL employees to increase their knowledge of chemical hazards. The Safety Officer can procure films from XYZ's Safety Video Library located in the Safety Division Office.

G. Safety Supplies/Equipment

Laboratory safety supplies and equipment such as protective gloves, goggles and aprons or protective apparel, fire extinguishers, emergency eyewash and

showers, fire blanket, Spill Tamer Kit, emergency oxygen, and first aid kit shall be inspected *each month* by the Safety Officer or Safety Technician for completeness and proper operation.

The Safety Officer or Safety Technician will be responsible for keeping safety supplies and equipment in stock and functioning properly.

XI. EMPLOYEE EXPOSURE EVALUATION AND MEDICAL CONSULTATION

This section of the program addresses the need for performing a formal evaluation of a suspected employee exposure to a hazardous chemical in the laboratory.

Contributing factors for exposure to hazardous chemicals such as failure to use proper protective apparel and equipment or failure to follow outlined safe work practices will be evaluated. Any deficiency found shall be corrected immediately to avoid the same problem in the future.

A. Criteria for *reasonable* Suspicion of Exposure

1. The employee had direct skin or eye contact with the chemical.
2. Manifestation of health hazard symptoms such as headache, rash, nausea, irritation of nose or throat, coughing, dizziness, tearing, irritation or redness of the eyes, etc.
3. Some or all of the symptoms disappear when the employee is away from the work area and into fresh air.
4. Symptoms reappear as soon as the employee returns to the work area.
5. Complaints are received from more than one employee.
6. An unusual odor is noticed in the work area.

B. Exposure Evaluation

The following steps shall be taken to determine the employee's exposure and medical attention needed.

Note: If it is necessary for the employee to receive immediate medical attention, appropriate action shall be taken before the following steps are taken.

1. Interview the employee or the victim initiating the complaint.
2. Gather essential information regarding the complaint such as (1) suspected chemical; (2) chemicals present in the work area; (3) symptoms; (4) were control measures such as protective apparel and equipment used; (5) duration of exposure, route of exposure, concentration of the substance in its container; (6) area of the room where exposure occurred; (7) severity and type of symptoms experienced; and (8) are all important factors properly recorded.
3. In cases where there is concern about overexposure to a chemical or chemicals, personal air sampling/environmental air sampling shall be performed by the Safety Division in order to determine the level of exposure.
4. The decision must be made as to the need to send the employee to medical consultation.

A memorandum documenting the complaint and outcome of the investigation regarding the complaint shall be written and forwarded to the Human Resource and Safety Divisions. A copy of the memorandum shall be given to the victim.

C. Medical Consultation

Employees known to have been overexposed to hazardous chemicals shall receive prompt medical attention. The employee will be sent to a medical facility or specialist as assigned by XYZ. Additionally, a first report of accident must be completed by the employee's supervisor and a copy must be sent to the Human Resource and Safety Divisions.

The employee will be notified of the outcome of the medical examination.

D. Exposure/Medical Records

Records of (1) employee exposure to hazardous chemicals, (2) investigation conducted and outcome, (3) medical attention required, and (4) results shall be kept on file and made available to affected employees upon their request.

XII. TRAINING RECORDS/DOCUMENTATION

Employee safety training efforts shall be documented in compliance with the Hazard Communication and Laboratory Standards information and training requirements. The documentation shall include the following information:

1. List of employees who attend the training
2. List of absentees to ensure that they receive the required training at a later date
3. Type of training received or list of topics discussed
4. Date
5. Employee acknowledgement

All employee safety training records shall be kept in a binder or folder titled "Employee Safety Training Records."

XIII. ACCIDENT REPORTING PROCEDURE

- A. All accidents and injuries are to be reported immediately.
- B. The standard form (generic lab form) will be used to report on-the-job injuries regardless of severity.
- C. The supervisor will complete the injury report form with all the necessary information regarding the exact nature of the injury.
- D. The supervisor will then submit the report to the Human Resource and Safety Divisions.

Summary and Miscellaneous Components of CHP

The Chemical Hygiene Plan for each environmental laboratory will be site specific; thus, it will differ somewhat from the sample CHP discussed in this chapter. The importance of the sample CHP discussed here is that it provides a written template upon which you can fashion your own CHP. It should be pointed out that in addition to the

sample CHP illustrated above, there are other component parts that usually make up the laboratory CHP. For example, your site-specific CHP should contain appendices with the following information:

1. Phone numbers of poison control center, hospital list, and emergency squads
2. A copy of the type of First Report of Accident that your firm uses
3. Physicians list
4. Designation (by name) of laboratory safety personnel (e.g., Lab Safety Officer, Hazardous Waste Coordinator, Assistant Safety Officer, Safety Technician)
5. Chemical Exposure Limit List

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CHAPTER 8

Safety Showers/Eyewash Stations

Safety showers and eye wash fountains must be at easily accessible locations for all employees working in the laboratory or with/around hazardous chemicals. The location should be such that the employees would not be tempted to place boxes or other items in such a position to restrict access to the shower or eye-wash.

—L. H. Phifer (1991)

Case Study 8.1: Freddie Krueger's Clone

Limon's Environmental Laboratory (LEL) was in business for eight years. The key word is "was"; Limon's went bankrupt and out of business a few months ago. The bankruptcy resulted from extraordinary litigation fees brought about by lawsuits generated by former employees and regulatory fines resulting from many instances of noncompliance with federal, state, and local standards. In a few instances, heavy expenditures were incurred for expenses generated both from litigation and fines.

As a case in point, let's take the accident that occurred with Al English. It all began on an overcast day in early October. One of the laboratory technicians was in the chemical storeroom drawing off a 1-liter sample of concentrated sulfuric acid from a 5-gallon carboy container. After filling the 1-liter bottle, the technician left the chemical room and started back toward his work station.

When he arrived at his work station, a lab assistant met him at the door and stated the lab manager wanted to see him ASAP. Without thinking, the lab technician set the 1-liter bottle of concentrated sulfuric acid on the lab bench and left for the lab manager's office.

The lab technician was informed that the lab technician had a serious problem at home that needed to be taken care of. The lab technician left for home immediately.

Meanwhile, back in the laboratory, the unlabeled 1-liter bottle of concentrated sulfuric acid sat on the lab bench for the rest of the day.

Each day, a few minutes before closing time, the laboratory assistants routinely cleaned off the lab benchtop work areas. Usually this function was completed with some haste because the lab workers were anxious to head for home.

The unlabeled 1-liter bottle of concentrated sulfuric acid was moved aside toward the back of the workbench. The worker who moved the bottle had no idea what was in it because the bottle was not labeled.

Later that evening, Al English was in the LEL to perform his custodial duties. When he came across the unlabeled 1-liter bottle of concentrated sulfuric acid, Al had no idea what substance was in the unlabeled bottle. From the outside it appeared to be a pale yellow, watery substance. Any other custodian might have left the bottle alone, but Al was a stickler for perfection. He believed that the laboratory lab tops should be clean and *clear*.

So when he picked up the unlabeled 1-liter bottle of concentrated sulfuric acid his intention was to move it, to place it somewhere other than on the bench top. The problem was he did not know where to put it because he did not know what it was.

Then he made another mistake.

Al picked up the unlabeled 1-liter bottle, unstopped the bottle top, brought the container to his nose, and inhaled deeply. The horrible acrid vapor attacked his nostrils, throat, and lungs. He jerked spastically, spilling about half the container on his face, throat, and the hand he was holding the bottle with.

While on his knees, screaming in pain, blinded, Al was able to crawl (using his elbows for propulsion) to the nearest emergency deluge shower. Finally, in the blackness of blindness he was able to feel for and find the emergency foot pedal. With pedal in hand, a micro-second of relief shot through his boiling brain cells. However, this was a wasted thought and effort because the emergency deluge shower had been inoperative for several years; the water supply line had been disconnected for maintenance that was never completed.

Eventually, several hours later, Al English, found passed out on the LEL floor, his good hand still gripping the emergency foot pedal, was taken to the local hospital where he was treated for severe chemical burns to his face, neck, chest, lower trunk, and right hand/wrist; both eyes were completely gone—just two empty sockets, forever open, perpetually staring into nothingness.

For months after this incident, Al English was the recipient of several sessions of plastic surgery in an attempt to restore his horribly burnt and disfigured face. The medical staff, under their breath, careful to ensure no one was listening, referred to their horribly disfigured long-term patient as “Freddie” (for Frederick Charles Krueger, the well-known horror movie star). Unfortunately, medical experts were unable to do much with Al’s eyes; they were beyond repair. The head nurse commented that all Al English needed was a set of evil-looking eyeballs, a red and green striped sweater, brown fedora hat, and a metal-clawed leather glove and he would be the perfect clone of Freddie Krueger. The fact that nothing could be done to restore Al’s eyes might be a godsend, the medical staff whispered. The med-

ical staff knew that if Al could see, he certainly would be appalled by his mirrored appearance.

In previous chapters information was presented concerning the various types of personal protective equipment (PPE) required to protect laboratory and chemical industry workers. It was also pointed out earlier that putting complete reliance on PPE to protect workers is not recommended. Instead, elimination of the hazard or use of engineering controls should always be incorporated first. The idea is to present no hazard or to “engineer out the hazard”—to get rid of the hazard, if possible.

Those who have worked out there in the “real world” know from experience that it is impossible to eliminate or engineer out every safety and health hazard. With this point in mind, designers, architects, engineers, and safety professionals try to identify the hazards that cannot be engineered out and provide for reasonable accommodation. This accommodation comes about in providing suitable safety and emergency equipment, which should be strategically placed, for easy worker use, throughout the industrial chemical facility.

This chapter deals with two vital safety and emergency systems that are required to be installed in workplaces that use, produce, or handle chemicals: eyewash fountains and safety showers. Before beginning discussion of these two critical safety systems it should be pointed out that the environmental laboratory and/or chemical industrial facility is required to be outfitted with several different types of safety equipment. In other chapters, most of this important safety equipment is described, including standard laboratory/chemical industrial facility safety equipment such as chemical spill kits and fire extinguishers. For now it should be emphasized that it is the *responsibility* of the organizational safety practitioner and/or the chemical hygiene officer (CHO) in laboratories to recommend and provide the supplementary safety and emergency equipment needed (Hall 1994). In addition, the safety person is responsible to ensure that all safety equipment is operational at all times (remember Freddie Krueger’s clone). This includes ensuring that all safety equipment is tested on a routine basis, and that it is repaired and/or replaced as needed.

Based on several years of safety management experience, we have found that situations like the one described in case study 8.1 are not all that uncommon. This is especially the case in regard to safety eyewash/deluge shower stations that are inoperable. For example, it is common to find as many as half of an organization’s eyewash stations in some state of disrepair. Such situations are totally unsatisfactory, dangerous, and unlawful. OSHA makes the requirement clear in the following:

[General industry.] Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use. (29 CFR 1910.151[c])

[Construction industry.] Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use. (29 CFR 1926.50[g])

As can be seen from the above statements, the OSHA regulation regarding emergency equipment is quite vague, in that it does not define what constitutes “suitable facilities” for drenching the eyes or body. In order to provide additional guidance to employers, the American National Standards Institute (ANSI) has promulgated a voluntary standard covering emergency eyewash and shower equipment. This standard—ANSI Z358.1—is intended to serve as a guideline for the proper design, performance, installation, use, and maintenance of emergency equipment. In this chapter we point out requirements for eyewash and shower stations based on ANSI recommendations and on personal experience in the field.

Did You Know?

29 CFR 1926.50(g) applies in all construction situations, except that battery handling is addressed in 29 CFR 1926.441(a)(6), which states:

Facilities for quick drenching of the eyes and body shall be provided within 25 feet (7.62 meters) of battery handling areas.

Eyewash Fountains and Emergency Showers

Whenever an employee receives a serious injury while on the job, this is a tragic event—an event usually caused when someone or something has failed in one way or another. For now this discussion is not concerned with causal factors but with preventive measures that can and should be employed to prevent or reduce the possibility of personnel injury in the chemical industrial workplace.

During chemical safety training sessions we conduct, we always begin with an “eye-opener,” so to speak. We have found that when it comes to eye protection safety training, the trainer need only ask the audience a few simple questions: (1) How devastating would it be for you to lose your eyesight? (2) Other than loss of life, is there any other injury that would be more devastating to you than loss of your eyesight? (3) When you talked to someone face to face and he or she looked into your disfigured eyes, how would this affect you?

Another important question that needs to be answered by industry management and safety professionals is: What materials in the workplace require an eyewash and/or emergency deluge shower? Generally, the materials referred to here are those that can cause damage to the eyes or skin, or materials that are readily absorbed through the skin. They can be in the following forms:

- Liquids (most common)
- Gases
- Vapors
- Solids
- Mists

The preceding questions usually set the tone (a grim one at best) for the lesson that we subsequently present on the importance of eye protection. Experience has shown that chemical workers must learn the location of and the use of available safety and emergency equipment in their work area so that they can find them with eyes closed.

With eyes closed?

Yes! Absolutely.

This statement seems appropriate when you consider that when an employee fills his or her eyes with 30 percent sodium hydroxide solution (stronger than Drano), for example, his or her eyes will definitely be closed—if they are open, the employee will be blinded by the corrosive chemical, by the probing irritation, and by the excruciating pain. The point is that the chemical worker who is injured in such a manner will literally be blinded (eyes closed, vision impaired) and will have to find an eyewash station or fountain just as a blind person would.

The reader is probably thinking: How could such a stupid incident occur in the first place? Aren't chemical industry personnel supposed to wear protective eyewear any time they are handling chemicals?

Of course they are. However, remember that “incidents” do occur. When these incidents do occur, needed emergency equipment must be available and in good working order. Ask yourself this question: If you contaminated your eyes with a chemical during an incident, how would you feel if the closest eyewash station did not function?

Speaking about the closest eyewash fountain, it may surprise you to know that there are no fixed standards on the maximum acceptable distance of travel to reach an eyewash station. However, the National Safety Council has recommended that the travel distance should be no more than 25 feet or that the station take no longer than 15 seconds to reach. It is interesting to note that, in contrast to the National Safety Council's recommendation (and as mentioned earlier), the American National Standard Institute (ANSI) in its Z358.1-2004 standard “*recommends*” the following:

For eyewash and shower units:

- Accessibility of emergency showers and/or eyewash stations within 10 seconds or less (travel time). Appendix B of ANSI Z358.1-2004 states that an average person covers a distance of approximately 55 feet in 10 seconds, when walking at a normal pace.
- The eyewash and/or shower unit must be on the same level as the operation in question. The climbing of stairs to reach the unit in an emergency is not allowed.
- ANSI recommends that the unit be immediately adjacent to the hazard when the pH of the hazardous substance is less than or equal to 1 or equal to or greater than 12.
- The location of the unit must be well lit, highly visible, and marked with a highly visible sign.
- The unit must be operable at all times, with provisions to prevent unauthorized shutoff of the water lines to the unit.
- A sewer connection or drain is not required, unless a special hazard is posed by the water.
- Units are to be installed in accordance with the manufacturer's instructions.

For eyewash units only:

- Eyewash units must be installed so that the nozzles are 33–45 inches (83.8–114.3 cm) from the floor.
- Eyewash units must provide a minimum of 0.4 gallons per minute (1.5 liters per minute) or a potable water or commercial flush for 15 minutes. Eyewash fountains/stations should provide flow at 25 psi or less. This eyewash pressurized flow should be presented to the eyes in such a manner as to flood both eyes with aerated potable water. If the installed unit is intended to cover the entire face, then 3 gallons per minute is required according to ANSI 358.1.
- Eyewash units must provide a pressure-reduced divergent flow of flushing fluid.
- Eyewash units must be flushed weekly to remove any bacterial contamination (*Acanthamoeba*) and to verify proper operation. Plumbed units must be flushed for 3 minutes minimum.
- Where contamination can occur, nozzles must be protected from contaminants by covers (or caps) that do not require an extra step for removal beyond the activation of the unit.
- Self-contained and portable eyewash units must provide 0.4 gallons per minute (1.5 liters per minute) for 15 minutes (6-gallon capacity).
- Portable eyewash units should be used only where fixed installation is not feasible.
- In self-contained and portable eyewash units, the flushing fluid must be replaced after any use. In addition, it must be replaced at the intervals recommended by the manufacturer.
- Squeeze bottles are not acceptable eyewash units on their own. They cannot supply the required amount of water to adequately flush the eyes, and their use does not keep both hands free to hold the eyelids open.
- They can only be used as an interim protective measure, in conjunction with an approved eyewash facility, where installation difficulties are an issue.
- In the General Requirements for Dipping and Coating Operations standard (29 CFR 1910.124), drench hoses are allowed in lieu of an eyewash and shower at open-surface tanks containing hazardous liquids. The device must supply clean water provided by a hose $\frac{3}{4}$ -inch in diameter, 48 inches or longer, with a quick opening valve. Pressure should not exceed 25 psi.
- Many faucet-mounted eyewash devices do not meet ANSI construction requirements.
- If use is planned, the ANSI-approved faucet-mounted eyewash device must meet *all* requirements for plumbed eyewash units. This includes requirements for installation height, water temperature, unobstructed access, travel time, labeling, etc. Because of the need for immediate use, the water temperature at the sink must immediately meet temperature requirements at *all* times.

For showers only:

- In many installations, emergency eyewash stations are combined with emergency showers to form one compact unit. Whether this is the case or not, the emergency

shower, like the eyewash station, is standard safety equipment that must be installed in chemical industrial work areas for immediate first aid treatment of chemical splashes. The facility's safety showers must have a quick-opening valve that will allow for drenching the victim immediately and must be large enough to accommodate more than one person if necessary. The quick-opening valve must be closed manually.

- Showers must provide a flow of flushing fluid in a dispersed pattern at a minimum of 20 gallons per minute (75.7 liters per minute).
- Weekly checks of the shower must be conducted to flush the lines and to verify proper operation.
- Overhead showers should be mounted at a head height of 82–96 inches (208.3–243.8 cm).
- The valve actuator for the shower must be located less than or equal to 69 inches (173.3 cm) above the floor or platform.
- Along with properly locating the safety shower, it is important to ensure that the water supply feeding the shower is adequate. The water supply should be able to provide up to 30 gallons per minute. The temperature of the water supply to the safety shower is also important, but even more so than the temperature of eyewash station water. This is the case because the water from the deluge shower covers more of the body's surface area.
- The safety shower should be easy to operate and should remain on until it is deliberately turned off.
- Some caution must be used when locating these shower stations. Obviously, it would not be wise to install a deluge shower next to an electrical power panel. Another point to keep in mind is that portable electrical equipment should not be moved near safety showers.

THE BOTTOM LINE ON EYEWASH/EMERGENCY DELUGE SHOWERS

Whatever style, type, or model of eyewash/deluge shower station is chosen for use in the chemical industry, the main requirement is that the unit operate in the easiest manner possible. When a victim's eyes are contaminated with a chemical, the last thing this victim should have to worry about is how to activate a complicated eyewash station.

TRAINING REQUIREMENTS FOR EMERGENCY AND EYEWASH SHOWER UNITS

- Employees are to be trained on the location and proper use of emergency eyewashes and showers.
- The training must address the holding open of the eyelids, and the rolling of the eyeballs, to facilitate the flushing over the entire surface of the eye.
- If squeeze bottles are provided for use as an interim protective measure, the training must address proper use in conjunction with the provided emergency eyewash.

Did You Know?

When strong acids or strong alkaline materials make contact with the eyes, the damage occurs within fifteen seconds. If it takes longer than ten seconds to reach the unit, it may not be effective in minimizing the likelihood of tissue damage.

The chemical industry workplace may have all the safety equipment that it could possibly contain, but if the workers are not properly trained on the use of the equipment, what good is it? Remember, any training conducted must be documented. If training is not documented, it did not occur; this is certainly the view that OSHA and the courts will take.

Again, these ANSI specifications are recommendations only. When it comes right down to it, common sense should dictate where the lab's eyewash fountains are to be placed. Remember, the effectiveness of any eyewash station is dependent on its accessibility. Placing eyewash stations on the other side of doorways is not making them accessible. No one should have to open a door or doors to reach an eyewash fountain. No one who is blinded and in pain from chemical exposure should have to feel their way to a remote eyewash/deluge shower station. Depending on the size of the industrial facility, eyewash stations should be located along a normal path of egress; for example, in a facility's main corridor.

RULE OF THUMB

The maximum time to reach an eyewash fountain should be determined by the potential effect of the chemical.

This rule of thumb makes sense when you consider that if chemical workers routinely work with very strong acids, the emergency eyewash station should be located within arm's reach, at their elbow, or no more than 10 feet in all directions.

Personal Eyewash Stations or Squeeze Bottles

The personal eyewash is a supplementary eyewash that supports plumbed units, self-contained units, or both by delivering immediate flushing for less than 15 minutes. Personal eyewash stations usually are bottled, provided in buffered solutions, and enclosed in emergency stations. There are two major problems with personal eyewash stations: (1) they lack the volume of flow needed to properly flush the eyes of contaminant(s); and (2) the solution in the bottles may become contaminated. Therefore, personal eyewash stations are not suitable for use in the chemical industry.

Outdoor Eyewash/Shower Station

Another point to keep in mind if you are planning on installing an eyewash station/fountain outdoors is the weather. Experience has shown that it is not unusual for a safety auditor to audit an industrial facility and find an outdoor eyewash/shower station that is inoperative because the pipes are frozen or broken from freezing. It is important to ensure that outdoor stations are piped in such a manner that will ensure they are protected from the elements. Water at temperatures of 60°F to 70°F temperature (normal tap water temperatures) should be used for emergency eyewash stations.

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CHAPTER 9

Chemical Safety Program

People who work in chemical industries are exposed to many kinds of hazards. Because almost everyone works with or around chemicals, this can be said of most workplaces; in some, the hazards are well recognized—those of ordinary fire, for example—and the precautions to be taken are obvious. Chemical industry work, however, involves a greater variety of possible health and physical hazards (toxicity, chemical burns, fire, explosion) than does most work, and some of those hazards call for precautions not ordinarily encountered elsewhere. In particular, chemical industries must be prepared to deal with substances known to be hazardous, with the potential hazards of new substances, and with production process off-gases.

Under the Occupational Safety and Health Administration's (OSHA's) standards and guidelines, all chemical industry personnel (and other industry personnel who work with or around chemicals) are required to handle chemicals prudently. This is a sensible requirement, especially when one considers that chemical-handling operations in the workplace are likely to be among the riskiest work practices performed there.

The risks associated with the physical and health hazards as well as the chemical incompatibilities of hazardous chemicals are well known. The sudden, violent, and unforeseen hazards that may result from unsafe chemical-handling operations must be guarded against. In order to prevent such mishaps, several safety guidelines should be in place in the workplace. The purpose of this chapter is to provide a generic template for a chemical safety program that is based on several safe work practices and safety guidelines (used in actual practice) that should be part of the organizational culture of the chemical industry workplace or any other workplace where workers may be exposed to chemical hazards.

No workplace chemical safety program is complete without a hazardous waste disposal program. This is the case, of course, because if chemicals are used or produced in the workplace, waste will be generated—and much of this waste could be hazardous. The organization's hazardous waste disposal program can be a stand-alone program or can be integrated into the chemical safety program. In this chapter, in addition to the generic chemical safety program template that follows, we also provide a generic hazardous waste disposal program template that serves as a model and can be used as an information source or example to fashion your chemical safety and hazardous waste disposal programs.

Chemical Safety Program Sample Template

XYZ INDUSTRIES: CHEMICAL SAFETY PROGRAM

There are many ways to work with chemicals that can both reduce the probability of an accident to a negligible level and reduce the consequences to minimum levels should an accident occur. At XYZ, risk minimization depends on elimination of hazardous substances, engineering controls for chemical containment, safe work practices, the use of the least quantity of material necessary, the substitution of a less hazardous chemical for the more hazardous one, and, as a last resort, the proper use of personal protective equipment (PPE).

Note: Before beginning work at XYZ all new employees shall attend a mandatory new employee safety orientation session. These sessions are scheduled on a weekly basis by the Safety Division for all new employees and as annual refresher training for current employees. XYZ's chemical safety program will be discussed during these sessions.

Chemical Safety Guidelines for the Workplace

As with safe work practices, general safety guidelines are designed to control chemical hazards at XYZ. As mentioned above, control of these chemical hazards, of course, should start with engineering controls, followed by administrative controls, and finally by the use of personal protective equipment. Safety guidelines should be included whenever safety training is conducted for XYZ workers. Moreover, any time a standard operating procedure (SOP) is written for a particular XYZ work operation, it is important to include applicable safety guidelines. In this section several safety guidelines are outlined. These guidelines should be considered for inclusion into XYZ's training program and SOPs.

Along with the chemical safety guidelines and safe work and handling guidelines provided below, it is important for every employee, before beginning any operation involving the use or handling of chemicals, to ask "What would happen if . . . ?" The answer to this question will be dictated by the hazardous properties of the material and its intended use. Moreover, for the employee to answer this question, he or she must not only understand the hazards associated with the chemicals but also the equipment and procedures involved.

(1) GENERAL CHEMICAL SAFETY GUIDELINES

Always follow these guidelines when working with chemicals:

- Assume that any unfamiliar chemical is hazardous.
- Know all the hazards of the chemicals with which you work.

- Follow all chemical safety instructions precisely.
- Only the minimum quantities of chemicals consistent with normal work needs and requirements should be maintained.
- Consider any mixture to be at least as hazardous as its most hazardous component.
- Before chemicals/hazardous materials are received by XYZ personnel, XYZ management should ensure that workers have been trained on proper handling of the chemical and its storage requirements, and ensure that no chemical container is accepted without an adequate identifying label and MSDS. In addition, no container of chemical/hazardous material should be accepted unless it is thoroughly inspected to ensure it is damage- and leak-free.
- Chemicals in storage should be protected to preclude spills, leaks, fire, earthquake damage, and so on.
- Never use any substance that is not properly labeled.
- To minimize the risks associated with chemical incompatibility, each XYZ work center shall follow and adhere to XYZ's chemical segregation scheme for chemicals in storage to ensure that accidental breakage, leaks, or other mishaps to chemical containers do not result if they should react with incompatible materials.
- Storage practices for flammable liquids (flashpoint less than 100°F) include several guidelines. In general (according to the National Fire Protection Association's NFPA-45), proper storage practices include the following:
 - The quantities of flammable chemicals stored in the laboratory should be kept to a minimum.
 - Flammable liquids must be stored away from heat and ignition sources.
 - Small quantities (working amounts) of flammable chemicals may be stored on open shelves.
 - Flammables should not be stored in areas exposed to direct sunlight.
 - Flammable chemicals must be stored in flammable-liquid storage cabinets that have been approved by the NFPA.
 - The following safety practices should be observed:
 - Store only compatible materials inside the cabinet.
 - Do not overload cabinets; follow manufacturers' recommended quantity limits.
 - Follow NFPA guidelines for maximum allowable volumes.
 - Do not store paper, cardboard, or other combustible materials in a flammable liquid storage cabinet.
 - Flammable liquids in large quantities should be stored in metal safety cans. The cans should be used only as recommended by the manufacturer.
 - Peroxides may be explosive. This is especially the case when they are improperly stored or handled. If peroxides are used in the XYZ workplace, the following guidelines should be followed:
 - Store peroxide compounds away from heat and light sources.
 - Do not use metal containers, since some metal oxides can promote the formation of peroxides.
 - Always label peroxides with the date they were opened.
- Higher chemical exposure risk is associated with work operations such as weighing, pouring, siphoning, mixing, blending, stirring, and shaking. When performing these operations, care and caution are advised.

- When handling corrosives (acids and bases), wear appropriate personal protective equipment including clothing, apron, chemical-resistant gloves, and splash goggles/face shield. Use proper pouring techniques when pouring acids into water and conduct the procedure in a fume hood. In addition, all dilutions of corrosives must be performed in a hood.
- When handling flammables, keep flammable compounds away from ignition sources, such as open flame. Moreover, whenever transferring a chemical from one container to another or heating a chemical in an open container, use a laboratory fume hood.
- Whenever chemicals are transported outside the work area, the container should be placed in a secondary, nonbreakable container. Before moving these containers, ensure that caps are tight.
- Regardless of its hazard rating, minimize your exposure to any chemical.
- Use common sense at all times.

(2) MATERIAL SAFETY DATA SHEETS

Before using any chemical, read the container label and the appropriate Material Safety Data Sheet (MSDS). MSDSs are placed in binders at each of XYZ's "Right-to-Know" stations. Container labels and MSDSs are good sources of information for chemical safety. They provide the following information:

- Identification of the chemical
- Physical hazards
- Control of hazards
- Health hazards
- Whether it is a carcinogen
- Emergency aid and first aid procedures
- Firefighting procedures
- First aid measures
- Handling and storage information
- Exposure controls/PPE
- Stability and reactivity
- Toxicological properties
- Ecological information
- Regulatory information
- Transportation information
- Date of preparation and latest revision
- Name, address, and telephone number of manufacturer
- Miscellaneous information

(3) SAFE CHEMICAL HANDLING GUIDELINES

XYZ employees should treat all chemicals and equipment with caution and respect. Whenever working with chemicals, always do the following:

- Remove and use only the amount of chemicals needed for the immediate job at hand.
- Properly label, seal, and store chemicals in appropriate containers.
- When disposing of chemicals, follow XYZ waste disposal guidelines.
- Ensure chemical containers are not damaged or broken.
- Clean up chemical spills immediately.
- When an emergency occurs, follow XYZ emergency procedures.
- Do not pour hazardous chemicals down the sink.
- Do not store chemicals near heat or sunlight.
- Do not transport unprotected chemicals between work stations.
- Always use a secondary container when transporting hazardous or highly odorous chemicals.

(4) PERSONAL HYGIENE

Preventing exposure to toxic chemicals is a primary concern in chemical industry workplaces. Most sites contain a variety of chemical substances in gaseous, liquid, or solid form. These substances can enter the unprotected body by inhalation, skin absorption, ingestion, or through injection (puncture wounds). Contaminants 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. Along with wearing proper personal protection equipment (PPE), good personal hygiene will help minimize exposure to hazardous chemicals (NIOSH 1985).

When working with chemicals, follow these guidelines and special precautions:

- Do not eat, drink, smoke, or apply makeup around chemicals.
- Wash hands frequently and before leaving the work area. Also, wash hands before eating, drinking, smoking, or applying makeup.
- Do not sniff or taste chemicals.
- Follow any special precautions for the chemicals in use.
- Do not use workplace equipment to serve or store food or drinks.
- Remove contaminated clothing immediately.
- Properly dispose of contaminated clothing.
- Do not wear contact lenses near chemicals.

(5) HAZARD COMMUNICATION PROGRAM

XYZ Industries has a written hazard communication program (HazCom) that complies with OSHA standards. This program is contained in all XYZ “Right-to-Know” Station Binders and is also available from the Safety Division office. It requires the following:

- Employee training
- Labeling

- MSDSs
- Chemical inventory
- Recordkeeping requirements
- Emergency response plan/procedures

Refer to XYZ's hazard communication program and other sections in this guidance manual for detailed information on these topics.

An important part of hazard communication is labeling. Workers have a right to know what materials they are working with and the hazards those materials may expose them to. XYZ Industries uses the NFPA 704-B labeling system. The NFPA diamond is readily recognizable, is easy to read and understand, alerts employees to the known hazards in a particular location, and is the preferred hazard symbol of our emergency responders.

The following is a detailed explanation of the NFPA 704-B diamond hazard classification codes:

Health (blue):

- 4—Can cause death or major injury despite medical treatment
- 3—Can cause serious injury despite medical treatment
- 2—Can cause injury; requires prompt medical treatment
- 1—Can cause irritation if not treated
- 0—No hazard

Flammability (red):

- 4—Very flammable gases or liquids
- 3—Can ignite at normal temperatures
- 2—Iginites with moderate heat
- 1—Iginites with considerable preheating
- 0—Will not burn

Reactivity (yellow):

- 4—Readily detonates or explodes
- 3—May detonate or explode with strong initiating force or heat under confinement
- 2—Normally unstable, but will not detonate
- 1—Normally stable; unstable at high temperature and pressure
- 0—Normally stable and no reactivity with water

Special Hazard (white):

- Oxidizer—OX
- Acid—ACID

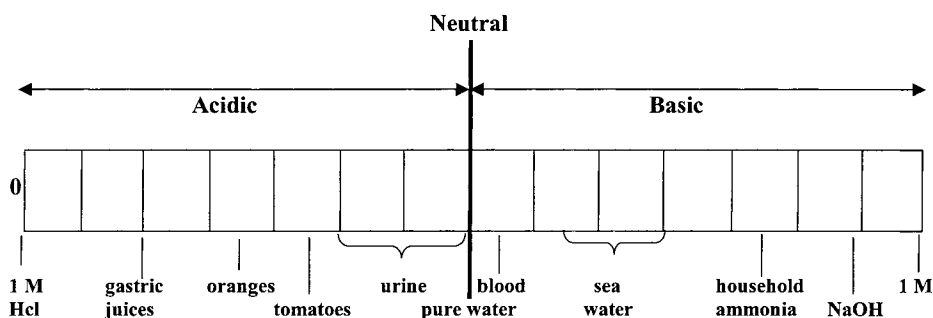


Figure 9.1. pH scale.

Alkali—ALK

Corrosive—COR

Use no water—~~W~~

Radioactive—RAD

(6) CORROSIVES

A corrosive chemical destroys or damages living tissue by direct contact. Some acids, bases, dehydrating agents, organics, and oxidizing agents are corrosives. As shown in figure 9.1, the pH value of a solution determines its acidity or alkalinity (basicity).

Important corrosives-related terms are defined in the following:

- **Albuminate:** a water-soluble protein, widely occurring in natural products such as milk, blood serum, and eggs. It readily combines irreversibly to form a clot or mass by the application of heat.
- **Anhydride:** a chemical compound derived when a molecule of water is eliminated from an acid.
- **Aqueous:** of, like, or formed by water.
- **Carboy:** a large glass bottle enclosed in a basketwork or a wooden crate and used for corrosive liquids.
- **Coefficient of expansion:** a coefficient for a substance that determines the extent to which a solid body or gas will expand when heat is applied.
- **Ester:** organic compounds (those containing carbon) corresponding to an inorganic salt and formed by the reaction of an acid and an alcohol.
- **Halide:** a compound containing halogens.
- **Halogen:** one of the very active chemical elements of Group VIIA of the periodic table: fluorine, chlorine, bromine, iodine, and astatine.
- **Litmus paper:** strips of paper containing blue amorphous powder. The paper changes color with the acidity or alkalinity of a solution—red at pH 4.5, blue at pH 8.3.
- **Outage:** a vacant space left in an enclosed container to allow for substances with high coefficients of expansion to expand as they are heated. Such substances include

compressed gases, corrosives, and flammables. The terms *freeboard* and *ullage* are also used.

- **pH value:** the strength of an acid or base. The pH is the negative logarithm of the hydrogen ion concentration and will usually be in the range of 1 to 13. This is because the actual hydrogen ion concentration values would otherwise cover too wide of a range to provide meaningful data.
- **Saponify:** to convert (as fat) into soap.

U.S. Department of Transportation (DOT) regulations consider a corrosive material to be a liquid or solid that causes visible destruction or irreversible alterations in human skin tissue at the site of contact, or in the case of leakage from its packaging, a liquid that has a severe corrosion rate on steel.

The U.S. Environmental Protection Agency (EPA), in regulating hazardous waste, uses pH value as the criterion for determining if a substance is corrosive. Wastes with a pH of less than 2.0 or greater than 12.5 are considered to be corrosive.

As pointed out in NCDOL (2007), the EPA defines corrosive waste to include (1) aqueous waste exhibiting a pH of ≤ 2 or ≥ 12.5 and (2) liquid waste capable of corroding steel at a rate greater than $\frac{1}{8}$ -inch per year. The EPA chose pH as one barometer of corrosivity because waste exhibiting low or high pH can cause harm to human tissue, promote the migration of toxic contaminants from other waste, react dangerously with other waste, and harm aquatic life. The EPA chose metal corrosion rate as its other barometer of corrosivity because waste capable of corroding metal can escape from the containers in which it is segregated and liberate other waste. (For additional information, see 40 CFR 261.22.)

All corrosive materials and solutions have the EPA hazardous waste number D002. The following is one of the more commonly used corrosive classification schemes:

- Acids and anhydrides (e.g., acetic acid)
- Alkalis (e.g., ammonium hydroxide)
- Halogens and halogen salts (e.g., aluminum chloride)
- Organic halides, organic acid halides, esters and salts (e.g., acetyl chloride)
- Miscellaneous corrosive substances (e.g., ammonium polysulfide)

Caution: Concentrated acids can cause painful burns that are often superficial. Inorganic hydroxides, however, can cause serious damage to skin tissues because a protective protein layer does not form. Even a dilute solution such as sodium or potassium hydroxide can saponify fat and attack skin. At first, skin contact with phenol may not be painful, but the exposed area may turn white due to the severe burn. Systemic poisoning may also result from dermal exposure.

Safe Handling Guidelines for Corrosives (Acids and Bases)

To ensure safe handling of corrosives, the following special controls and handling procedures should be used:

- As applicable, wear appropriate personal protective clothing (e.g., acid-resistant apron, chemical-resistant gloves, splash goggles, and face shield). Refer to the MSDS.
- Always store corrosives properly. Refer to the MSDS.
- Conduct chemical procedures in a fume hood.
- Use proper pouring techniques when pouring acids into water.
- Corrosives, especially inorganic bases (e.g., sodium hydroxide), may be very slippery; handle these chemicals with care and clean any spills, leaks, or dribbles immediately.
- Perform all chemical dilutions of corrosives in a fume hood.
- A continuous-flow eyewash station should be in every work area where corrosives are present. An emergency shower should also be within 10 seconds and no more than 100 feet of the chemical handling area.

Corrosive Example: Sulfuric Acid. Because of its widespread usage, sulfuric acid has been called the workhorse of the industrial world. Its popularity suggests that sulfuric acid is likely to be encountered more frequently than other corrosive materials in the workplace and during hazardous materials incidents.

Sulfuric acid is a mineral acid. It is a colorless, oily liquid having a density approximately twice that of water (see table 9.1). Commercially, sulfuric acid is sometimes encountered as a clear-to-brownish-colored liquid, which reflects a lower degree of purity.

The principal hazards associated with concentrated sulfuric acid are lined with the heat evolved when the acid is diluted, the ability of the acid to extract water from certain materials, and the ability of the acid to react as an oxidizing agent.

(7) FLAMMABLES

Fire occurs whenever heat, fuel, and oxygen are present. Remove any of these elements, and a fire will go out.

A flammable chemical is any liquid, solid, or gas that ignites easily and burns rapidly in air. In industrial settings, large inventories of flammable gases and flammable liquids are often stored for eventual use in connection with the manufacturing and processing of commercial products.

Table 9.1. Physical Properties of Concentrated Sulfuric Acid

Specific gravity	1.84
Vapor density (air = 1)	2.8
Boiling point	640°F (338°C)
Freezing point	50°F (10°C)
Solubility in water	Infinitely soluble
Chemical formula	H ₂ SO ₄

Even when exposed to an ignition source, there are unique minimum and maximum vapor concentrations below and above which a flammable liquid does not burn. These minimum and maximum concentrations are called the *lower explosive limit* (LEL) or lower flammability limit and *upper explosive limit* (UEL) upper flammability limit, respectively. For example, gasoline is a flammable liquid. Its lower explosive limit is 1.4 percent by volume, whereas its upper explosive limit is 7.6 percent by volume in air. These limits signify that a mixture of gasoline vapor having a concentration less than 1.4 percent by volume in air is too *lean* in gasoline vapor to burn; similarly, a mixture containing more than 7.6 percent by volume is too *rich* in gasoline vapor to burn.

The flammable range, sometimes called the explosive range, of flammable gases and the vapors of flammable liquids is the numerical difference between their upper and lower explosive limits. Thus, the flammable range of gasoline vapor is 6.2 percent by volume.

A flammable gas or vapor burns only when the concentration of the gas or vapor is exposed to an ignition source and its concentration in the air lies within the flammable range for the given substance. Thus, all concentrations of gasoline vapor between 1.4 percent and 7.6 percent by volume ignite when exposed to an ignition source.

The explosive limits of some gases and vapors are given in table 9.2. Concentrations are given in percent by volume of air.

In addition to their characteristic explosive limit, flammable chemicals are classified according to flashpoint, boiling point, and ignition temperature. Flashpoint (FP) is the lowest temperature at which a flammable liquid gives off sufficient vapor to ignite. Boiling point (BP) is the temperature at which the vapor pressure of a liquid vaporizes.

Table 9.2. Explosive Limits

<i>Substance</i>	<i>LEL</i>	<i>UEL</i>
Acetone	3%	13%
Acetylene	2.5%	82%
Benzene	1.2%	7.8%
Butane	1.8%	8.4%
Ethanol	3%	19%
Ethylbenzene	1.0%	7.1%
Ethylene	2.7%	36%
Diethyl ether	1.9%	36%
Diesel fuel	0.6%	7.5%
Gasoline	1.4%	7.6%
Hexane	1.1%	7.5%
Heptane	1.05%	6.7%
Hydrogen	4%	75%
Hydrogen sulfide	4.3%	46%
Kerosene	0.6%	4.9%
Methane	5.0%	15%
Octane	1%	7%
Pentane	1.5%	7.8%
Propane	2.1%	9.5%
Propylene	2.0%	11.1%
Styrene	1.1%	6.1%
Toluene	1.2%	7.1%
Xylene	1.0%	7.0%

Table 9.3. Flammable Class Characteristics

<i>Class</i>	<i>Flashpoint</i>	<i>Boiling Point</i>	<i>Examples</i>
1A	<73	<100	Ethyl ether
1B	<73	<100	Flammable aerosols
			Acetone
			Gasoline
			Toluene
1C	<73	<100	Butyl alcohol
			Methyl isobutyl ketone
			Turpentine
2	100–140	—	Cyclohexane
			Kerosene
			Mineral spirits
3A	140–199	—	Butyl cellosolve
3B	<200	—	Cellosolve
			Ethylene glycol
			Hexylene glycol

Flammable liquids with low BPs generally present special fire hazards. The FPs and BPs of certain chemicals are closely linked to their ignition temperature—the lowest temperature at which a chemical will ignite and burn independently of its heat source.

Table 9.3 illustrates flammable class characteristics. Table 9.4 provides examples of common flammables and their flashpoint and class.

Safe Work/Handling Guidelines for Flammables

Follow these guidelines and controls when working with or handling flammable chemicals:

- Keep flammable compounds away from ignition sources, such as an open flame.
- Never heat flammable chemicals with an open flame.

Table 9.4. Common Flammables

<i>Chemical</i>	<i>Flashpoint</i>	<i>Class</i>
Acetone	0	1B
Benzene	12	1B
Butyl acetate	>72	1C
Carbon disulfide	–22	1B
Cyclohexane	–4	1B
Diethylene glycol	225	3B
Diethyl ether	–49	1A
Ethanol	55	1B
Heptane	25	1B
Isopropyl alcohol	53	1B
Methanol	52	1B
Pentane	<–40	1A
Toluene	40	1B

- Use bonding and/or grounding straps when transferring flammable chemicals between metal containers to avoid generating static sparks.
- Conduct procedures in fume hood, especially while transferring chemicals from one container to another or heating chemicals in an open container.
- Heat flammable substances in steam, water, oil, hot air baths, or heating mantle.
- Restrict the amount of stored flammables, and minimize the amount of flammables present in a work area.

(8) SOLVENTS

Solvents are liquids or gases that can dissolve other substances. If they get into workers' bodies, organic solvents can harm the health of workers. Even small amounts can be dangerous. Solvents such as alcohols, toluene, and ether, for example, are highly volatile and flammable. Chlorinated solvents such as chloroform are nonflammable, but when exposed to heat or flame, they may produce carbon monoxide, phosgene, chlorine, or other highly toxic gases.

Exposure to solvents is addressed in specific standards for the general industry, shipyard employment, and the construction industry. Chemicals are commonly used in these industries, thus we list the specific OSHA standards below:

OSHA Solvent Standards

General Industry (29 CFR 1910)

- 1910 Subpart G, Occupational health and environmental control
 - 1910.94, Ventilation
- 1910 Subpart H, Hazardous materials
 - 1910.107, Spray finishing using flammable and combustible materials
- 1910 Subpart Z, Toxic and hazardous substances
 - 1910.1000, Air contaminants
 - Table Z-1, Limits for air contaminants
 - 1910.1200, Hazard communication

Shipyard Employment (29 CFR 1915)

- 1915 Subpart C, Surface preparation and preservation
 - 1915.32, Toxic cleaning solvents
 - 1915.35, Painting
- 1915 Subpart Z, Toxic and hazardous substances

Construction Industry (29 CFR 1926)

- 1926 Subpart D, Occupational health and environmental controls
 - 1926.55, Gases, vapors, fumes, dusts, and mists
 - Appendix A, Gases, vapors, fumes, dusts, and mists
 - 1926.57, Ventilation

Volatile and flammable solvents should only be used in areas with good local ventilation or in a fume hood. Never use highly flammable solvents in an area with open flames or other ignition sources present.

Solvent Health Hazards

Health hazards associated with solvents include exposure by inhalation of a solvent, which may cause bronchial irritation, dizziness, central nervous system depression, nausea, headache, coma, or death. Prolonged exposure to excessive concentrations of solvent vapors may cause liver or kidney damage. Skin contact with solvents may lead to defatting, drying, and skin irritation. Ingestion of a solvent may cause severe toxicological effects. Seek medical attention immediately.

To decrease the effect of solvent exposure, substitute hazardous solvents with less toxic or hazardous solvents whenever possible.

(9) TOXIC CHEMICALS

The toxicity of a chemical refers to its ability to damage an organ system (kidneys, liver), disrupt a biochemical process (e.g., the blood-forming process), or disturb an enzyme system at some site remote from the site of contact.

When working with toxic chemicals, these are general safeguards available to provide protection:

- Check with other chemical industrial operations performing similar work to investigate the procedures and safety precautions they are using.
- Have the needed toxic materials transferred from other work areas instead of purchasing additional material.
- Always work with the smallest amount possible.
- Label all containers with the chemical name and warning of the material's potential hazards.

Inhalation and dermal absorption are the most common methods of chemical exposure in the workplace. Always minimize your exposure to any toxic chemical.

Types of Toxic Chemicals

- **Acute toxins:** can cause severe injury or death as a result of short-term, high-level exposure. Never work alone when using acute toxins. To ensure proper ventilation, use a fume hood. Examples of acute toxins include the following:
 - Hydrogen cyanide
 - Hydrogen sulfide
 - Ricin

- Organophosphate pesticides
- Arsenic
- **Chronic toxins:** can cause severe injury after repeated exposure. Examples of chronic toxins include the following:
 - Mercury
 - Lead
 - Formaldehyde
- **Carcinogens:** can cause cancer in humans or animals. Several agencies, including OSHA, NIOSH, and IARC, are responsible for identifying carcinogens. There are very few chemicals known to cause cancer in humans, but there are many suspected carcinogens and many substances with properties similar to known carcinogens. When working with known or suspected carcinogens, zero exposure should be the goal. Workers who are routinely exposed to carcinogens should undergo periodic medical examinations. Examples of known carcinogens include the following:
 - Aflatoxins
 - Asbestos
 - Benzene
 - Chromium, hexavalent
 - Tobacco smoke
- **Reproductive toxins:** can produce adverse effects in parents and developing embryos. Chemicals including heavy metals, some aromatic solvents (benzene, toluene, xylene, etc.), and some therapeutic drugs are capable of causing these effects. In addition, the adverse reproductive potential of ionizing radiation and certain lifestyle factors, including excessive alcohol consumption, cigarette smoking, and the use of illicit drugs, are recognized. It is prudent for those with reproductive potential to minimize chemical exposure.
- **Sensitizers:** defined by OSHA as “chemicals that cause a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.”

The condition of being sensitized to a chemical is also called chemical hypersensitivity. Certain chemicals have no immediate health effect, but exposure to them several times can make you allergic or sensitive to other chemicals. A classic example is formaldehyde (CH_2O). Typical reactions to sensitizers can include skin disorders such as eczema.

- **Irritants:** can cause reversible inflammation or irritation to the eyes, respiratory tract, skin, and mucous membranes. Irritants cause inflammation through long-term exposure or high-concentration exposure. Examples of irritants include the following:
 - Ammonia
 - Formaldehyde
 - Halogens
 - Phosgene
 - Poison ivy
 - Sulfur dioxide

(10) REACTIVES AND EXPLOSIVES

Reactive and/or explosive chemicals are sometimes used or produced in chemical industry workplaces. Reactive chemicals are sensitive to either friction or shock, or they react in the presence of air, water, light, or heat. Explosive chemicals decompose or burn very rapidly when subjected to shock or ignition. Reactive and explosive chemicals are extremely dangerous because they produce huge amounts of destructive heat and gas.

Safe Work Practices for Working with or near Reactives and/or Explosives

In addition to the fundamental safety principles presented to this point, the following measures or practices should be used to reduce the risk of injury from reactives and/or explosives used or produced in the workplace:

- Ensure elimination or control of sources of ignition.
- Ensure separation of processes that use flammable chemicals.
- Ensure provision of an inert atmosphere for totally enclosed processes and handling systems.
- Ensure provision of means of fire detection and alarm which, as far as is practicable, should include automatic means of extinguishing incipient fires.
- Ensure installation of means of detecting increases in pressure and the automatic operation of a gas suppressor to prevent an explosion (e.g., for dust explosion).
- Ensure use of the provided engineering control measures .
- Ensure minimization of the quantities of chemicals kept in the workplace.
- Ensure separation of incompatible chemicals.
- Ensure procedures for immediate spill cleanup.
- Ensure safe disposal of chemicals and chemical waste.
- Ensure use of non-sparking tools.
- Ensure hazard areas are properly posted (signs, labels, etc.).
- Ensure availability and proper donning of PPE.
- Ensure emergency response procedures are in place and practiced.

(11) CLEANING AGENTS

Exposure to cleaning agents in the workplace is usually by inhalation of vapors or mists, or by contact with skin or eyes. The most common effect on health after exposure is irritation—pain and inflammation, sometimes accompanied by redness and swelling—of the skin, eyes, or respiratory tract. Follow these guidelines when working with any cleaning agent:

- Always follow the label instructions and MSDS guidelines.
- Never mix cleaning agents with other cleaning agents.
- When diluting acid with water, always add the acid to the water, not the water to the acid.
- Wear appropriate PPE (eye and hand protection).

(12) VENTILATION

A typical chemical industry workplace has several types of ventilation. Exhaust ventilation systems are of two types: (1) general exhaust systems and (2) local exhaust systems. Ventilation can be used either to capture contaminants and remove them or to dilute contaminants to safe levels.

General Exhaust (Dilution) Ventilation

General exhaust or dilution ventilation can be used for both heat control and/or contamination removal. Dilution occurs when contaminants mix with air flowing through the work area. Usually, contaminants are diluted by mechanically induced air movement with a large volume of outside air drawn in and mixed with it. The contaminated air is then discharged to the outside atmosphere. The major disadvantage of dilution ventilation is that a large volume of dilution air may be needed. Thus, this system is normally used for contaminant control only when local exhaust is impractical.

Local Exhaust Ventilation

In general exhaust ventilation the objective is to dilute the contaminant; on the other hand, in local exhaust ventilation the objective is to *capture* the contaminant. Local exhaust ventilation is the preferred method of control because it is more cost effective relative to dilution ventilation, where huge volumes of air can be moved at any given moment. In addition, local exhaust ventilation is usually more economical whenever it is tied into the facility's HVAC system, where return air must be preheated. Obviously, it is less costly to preheat small volumes of return air as compared to the huge volumes that are typical with general exhaust ventilation systems. Another huge advantage of local exhaust ventilation, especially in the laboratory environment, is that it provides better control of the contaminant. This greater control is obtained by having the exhaust device surround or enclose the source, as would be the case in a fume hood. Of course, the benefit received from having greater control of the contaminant is that gases and particles that are small enough to be breathable normally follow the airflow; control of the airflow provides control of the contaminant and protects the user. Simply stated, local exhaust systems work to capture or contain contaminants at their source before they escape into the workplace environment; thus, they work to protect (by providing positive control over exposure) those who work in the chemical industry.

Local exhaust systems consist of such devices as bench slots, canopy hoods, elephant trunks, back draft benches, and laboratory fume hoods. It is the standard fume hood that is the focus of discussion in this section.

A typical local exhaust system consists of five components: hoods, duct system, air cleaning device, fan, and an exhaust stack.

A *hood* is a shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system; the hood is the most important part of the local exhaust ventilation system. The purpose of the hood is to collect the contaminant generated in an

air stream directed toward the hood. Both the design and location of the hood are crucial in determining whether the system will work as expected. There are three types of hoods, each working on a different principle:

- Enclosure hood
- Receiving hood
- Capturing hood

The *enclosure hood* surrounds the contaminant source as much as possible. This type of hood has a low exhaust rate, with an inward face velocity of between 100 and 150 ft/min. Contaminants are trapped inside the enclosure by air flowing in through openings in the enclosure.

The *receiving hood* is used for processes that generate a waste stream of contaminants in one specific direction. For example, a blast furnace that emits a hot stream of air and gases above it would need an exhaust system mounted directly above it. This would facilitate catching the contaminants when they are generated. These hoods are generally not used where health protection is an issue. This is because these hoods operate on low-velocity airflow. When the airflow is low-velocity gases, vapors, and very small particles that do not travel very far, high-velocity moving air is required.

The *capturing hood* actually reaches out into the workplace to capture contaminants in the air. These hoods are widely used in industry because they can be placed alongside the contaminant source rather than surrounding it with an enclosure hood. Capturing velocities as low as 50 ft/min to as high as 2,000 ft/min are typically used. The capturing hood does have two major disadvantages: (1) large air volumes may be needed to generate an adequate capture velocity at the contaminant source; and (2) the reach of most capturing hoods is limited to about two feet from the hood opening. This second disadvantage is in line with the well-known ventilation adage that says it is easier to provide a strong blowing force (supply) than it is to provide a strong sucking force (exhaust).

In selecting the proper hood for the environmental laboratory, it is important to keep a couple of factors in mind. First, each hood type works on a different principle and has a very distinct purpose. Second, selecting the proper hood will depend on the type of contaminants that are or will be generated inside the environmental laboratory. Gases, vapors, and particulate matter in respirable size go with the flow—that is, they move along with the airflow. Contaminants are thus controlled by regulating the airflow around them.

Ducts are a system or network of piping that connects the hoods and other system components. An *air cleaner* is a device that removes atmospheric airborne impurities such as dusts, gases, vapors, smoke, and fumes. The *fan* provides the motive force (energy) to draw air and contaminants into the exhaust system by inducing a negative pressure or suction in the ducts leading to the hoods. The *exhaust stack* provides a safe outlet for contaminants to the atmosphere. These stacks are normally positioned in such a manner to preclude exhausted air and contaminants being recirculated with outside supply air.

Heat Control Ventilation

Heat control ventilation (sometimes called comfort ventilation) is used to control indoor atmospheric conditions associated with hot industrial environments such as those found in laundries, foundries, bakeries, and so on, for the purpose of preventing worker discomfort. In many laboratories, there are significant heat sources that can cause an elevation of the workplace temperature. Obviously, this is not a good or comfortable situation for the workers. Thus, exhaust ventilation is provided to control the heat and humidity to provide comfort.

Supply Ventilation

Whenever several devices such as fume hoods work to exhaust air from the workplace, obviously an equal quantity of air must be supplied. If the air supply system is inadequate (under-designed or inoperative), then supply air will get inside the laboratory through infiltration, backdrafting in inactive hoods, or by some other undesirable method. Consequently, a dedicated air supply system is required to ensure proper operation of the exhaust ventilation system and workplace comfort.

The Ideal Mix

Even though supply or return air is required to provide replacement of air that has been exhausted, the supply and exhaust systems in the typical chemical industry workplace work on two different principles. Gentle removal of contaminants is the function of exhaust systems. Supply systems, on the other hand, provide control of environmental conditions by thoroughly mixing the air in the room. Because supply causes churning or mixing of the air and because exhaust systems have to overcome these actions to properly remove contaminants, there must be an ideal mix or balance between the supply and exhaust ventilation system. Under normal conditions, it is desirable to maintain a balance between supply and exhaust—to have approximately the same supply and exhaust for each laboratory unit. However, there are other instances where it may be desirable to provide an intentional imbalance. For example, there may be cause to provide positive or negative conditions in the laboratory to provide a secondary level of control. For instance, when more air is exhausted from a laboratory than is provided through the supply air system, the room is “negative.” When this occurs, air will flow through openings and there will be a migration from the corridors into the laboratories. This might be the desired effect. That is, under a significant chemical or contaminant release or spill condition, the negative condition will maintain the chemical or contaminant within the laboratory without exposing outside personnel.

Safe Work Practices: Using Fume Hoods

Before beginning a detailed discussion of recommended safe work practices to be observed and performed with fume hoods in the environmental laboratory, it is impor-

tant to discuss a few fundamental concepts. For example, at the heart of safe operation of fume hoods is the *face velocity* of the hood. Face velocity refers to the average air velocity into the exhaust system measured at the opening into the fume hood.

OSHA, under its 29 CFR 1910.1450 (Laboratory Standard), is very specific about maintaining the face velocity of laboratory fume hoods within certain ranges, depending on the toxicity of the contaminant. The higher the toxicity (threshold limit value—TLV), the higher the face velocity required to ensure adequate protection for the worker. At a minimum, OSHA requires laboratory fume hood face velocities of 60–100 ft/min. A list of the required face velocity levels for use with chemicals with varying levels of toxicity in fume hoods is provided in table 9.5.

Exhaust Hoods. NIOSH (1973) points out that the local exhaust “hood” is the point at which air enters the exhaust system, and the term is used in a broad sense to include all suction openings, regardless of their shape or their physical disposition. Hoods in the context of this discussion about industrial chemical applications embrace all types of such openings including suspended, canopy-type hoods, booths, exhausts through grille work in the floor or benchtop, slots along the edge of a tank or table, the open end of a pipe, and, in a general sense, exhaust from most enclosures. Exhaust hoods exhaust toxic, flammable, noxious, or hazardous fumes and vapors by capturing, diluting, and removing these materials. Exhaust hoods also provide physical protection against fire, spills, and explosion. Exhaust hoods (fume hoods) provide the best protection when the hood sash is in the closed position. All chemical fume hoods must be ducted to the outside of the building.

Hoods ventilate chemical process equipment by capturing emissions of heat or air contaminants, which are then conveyed through ductwork to a more convenient discharge point or to air pollution control equipment. The quantity of air required to capture and convey the air contaminants depends upon the size and shape of the hood, its position relative to the points of emission, and the nature and quantity of air contaminants.

Exhaust hoods should enclose as effectively as practical the points where the contaminant is released. They should create air flow through the zone of contaminant release of such magnitude and direction as to carry the contaminated air into the exhaust system. Exhaust hoods and enclosures may also serve the important function of keeping materials in the process by preventing their dispersion.

Hoods can be classified conveniently into three broad groups: enclosures, receiving hoods, and exterior hoods. Booths such as the common spraying-painting enclosure are a special case of enclosing hoods.

Table 9.5. Face Velocity for Fume Hoods

<i>Chemical Toxicity Level</i>	<i>Required Face Velocity Range</i>
Chemicals of low toxicity	70–80 fpm
Chemicals of moderate toxicity	100 fpm
Chemicals of high toxicity	125–150 fpm

When working with fume hoods, workers—in order to receive the full protection afforded by the hood—should follow the safe work practices listed in the following:

1. Chemical operations that release significant quantities of airborne contaminants should be conducted inside the hood.
2. The user should keep all containers and apparatus several inches back from the front of the hood. Moving an apparatus several inches back from the front edge of the hood can reduce the vapor concentration at the face by 90 percent (Hall 1994).

Note: It is important to keep in mind that the performance of the hood depends on placement of equipment in the hood, room drafts from open doors or windows, people walking by, and even the presence of the user in the front of the hood.

3. Keep head outside hood enclosure when operations are under way.
4. Except for quantities of volatile materials of less than 50 ml, the fume hood should not be used for evaporating waste for disposal purposes.
5. Do not store chemicals in hoods; chemicals should be stored in approved storage cabinets.
6. Keep the hood sash closed as much as possible. Keeping the face opening of the hood small will improve the overall performance of the hood.
7. Do not obstruct the baffles or slots in the rear of the hood.
8. If there is the possibility of an explosion, a safety shield or barricade must be used.
9. Keep laboratory windows and doors closed.
10. Control traffic past the hood.
11. When in use, the hood must be turned on.
12. Except for repair or routine maintenance, do not remove any component part of the hood.
13. Only use a fume hood that is approved for use (i.e., one that has been properly maintained and tested).

Testing Hoods

Periodic checks or tests of laboratory fume hood performance are important in protecting workers' health. With normal use the hood's efficiency in containing or capturing contaminants may decrease for many reasons: normal wear, loose component parts (e.g., fan belts), out-of-adjustment dampers, clogged air cleaners, and ductwork blocked by dust and debris.

It is important to keep in mind that even though the fume hood equipment might be performing up to standards it may still not provide enough protection for the user. The point is that no matter how well the unit checks or tests out, the system is not performing adequately if air samples show excessive employee exposures. One can only be sure that the hood system is providing sufficient protection if hood system tests can be correlated with air contaminant concentrations.

Several different tests are available to help determine how the hood system is operating. These tests consist of: hood static pressure; Pitot tube duct velocity measure-

ments; velocity at the hood opening; smoke tube tracers; and fan pressure, rotating speed, and power consumption. Along with performing such tests on the hood system to check how it is operating, routine maintenance should also be performed on a regularly scheduled basis.

Daily and before-use inspections/tests. At a minimum, daily/before-use and quarterly inspection and testing should be conducted on fume hoods. The daily or before-operation inspection should consist of an *airflow check*. A simple qualitative check that can be used to check for proper airflow, exhaust, is the ribbon or tissue paper check. During this test, a ribbon or piece of tissue paper (be careful not to lose control of these for they could gum up the system) is placed at the hood opening to determine if it reflects directional airflow. Daily and before each use the hood gauges and monitors should be checked for proper operation within a predetermined range.

Daily and before each use the hood should be checked to ensure that material is not blocking the hood opening or exhaust ports. This housekeeping procedure should also include checking the fume hood to ensure that there are no puddles of spilled materials pooled within.

Quarterly inspection and testing. *Face velocities* for laboratory fume hoods should be measured on a quarterly basis. These tests should be conducted by qualified personnel using a properly calibrated velometer. *Smoke tube or smoke candle tests* should be performed quarterly to evaluate airflow patterns.

The practice of conducting these daily and quarterly inspections and tests on fume hoods should be made part of the workplace safety training program. In addition, to ensure maximum protection, workers should observe the safe work practices outlined above.

Emergency Response Procedures

Having an emergency plan will not mean that a disaster will not happen, but with a plan in place, the chances of an accident becoming a disaster are greatly diminished. An emergency plan should be constantly reevaluated and updated to ensure that changing conditions and personnel are taken into account. An obsolete plan is little better than no plan at all.

—J. Newton (1987)

The very nature of working in a workplace with hazardous chemicals makes emergencies very real possibilities. These emergencies strike suddenly and unexpectedly and require immediate response. Although it is the accidents with hazardous materials that are most likely to lead to emergency response situations in the workplace, other possible emergency situations must also be taken into account. For example, fires, storms (hurricanes and tornadoes), earthquakes, electrical shock, power failure, and medical emergencies are real possibilities (these events may be related to [in the case of fire and medical problems] or compounded by hazardous materials, but not in every situation).

This section addresses emergency response procedures used to control and contain loss of property and prevent injury to workers in the chemical industry workplace due to fire, explosion, toxic chemical spill, and/or accidents. Moreover, an emergency response procedure, currently used in a chemical industry workplace, is presented as an example of the type of procedure that is required. Along with standard emergency response procedures for use in the workplace, several work practices related to specific workplace equipment is included. Finally, emergency medical response procedures for the chemical industry workplace are discussed.

EMERGENCY RESPONSE: REQUIREMENTS

When a hazardous materials (hazmat) incident occurs, decisive action is immediately required. Decisive action, however, cannot be taken in a safe and sound manner unless those reacting follow a plan, a routine, and a protocol that will allow them to mitigate the situation with the least degree of danger to themselves, others, and the environment. Because of the need for decisive action and a written plan of action for hazardous materials incidents that may occur in the workplace, OSHA has mandated two basic but far-reaching requirements:

1. Every workplace where hazardous materials are used or produced is responsible for having a comprehensive emergency action plan that complies with OSHA's Standard on Emergency Plans and Fire Prevention Plans (29 CFR 1910.38). This emergency action plan must be readily available for implementation during emergency events.
2. OSHA also has a special regulation dealing specifically with spills of hazardous chemicals. This regulation, called the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard, is found at 29 CFR 1910.120 and has direct applicability to the chemical industry workplaces where hazardous chemicals are used.

At the heart of safe work practices with hazardous materials handling is good emergency planning. Hazardous materials mishaps are always characterized by their potential for complexity (Hall 1994). This is why OSHA specifically mandates emergency planning.

The chemical industry workplace's emergency plan should address actions to be taken in case of fire and/or explosion and should include, at a minimum, the following:

- A list of emergency numbers to be used to alert workplace personnel, local police, fire, emergency rescue, and medical personnel
- The preferred means of reporting fire and emergencies
- Names and phone numbers of personnel to be contacted in an emergency
- Rescue and medical duties for those who are designated to perform them
- Emergency escape procedures and emergency escape route assignments

- Procedures to account for all employees after an emergency evacuation
- Procedures to be followed by employees who remain to operate or shut down operations before they evacuate
- Material Safety Data Sheets (MSDSs) detailing the chemical and physical properties of hazardous materials stored or handled in the workplace, and specific emergency response measures to be implemented to contain these materials in the event of an emergency

Even with a written plan, it is important to keep in mind that under no circumstance should untrained personnel respond to a hazardous materials incident.

SAMPLE EMERGENCY RESPONSE PROCEDURE

The following protocol is an example procedure used in a chemical industry workplace. This procedure is beneficial because it has proven its worth; it has been tested.

Procedures for Cleanup of Hazardous Materials Spills

1. Slightly hazardous materials (weak acids, bases, oils, etc.)
 - Absorb using paper towels, shaker dispensed Spill-X-A type for acids and Spill-X-C type for caustic or basic substances, spill-control pillows.
 - Transfer to a plastic bag, place in trash container for solid wastes. Clean floor (or other spill surface) thoroughly with soap and water; dry surface completely to prevent slips or falls.
2. Mercury spill
 - Contain the spill in a small area and warn coworkers not to walk on spill area.
 - Use gloves and remove any sources of heat that might volatilize the mercury. Do not use an ordinary vacuum cleaner; it will aerosolize and spread the mercury all over the workplace.
 - If the mercury has reached a porous surface (floor, workbench, etc.), special chemical inactivators must be used. Hg-X is mixed with water and the contaminated area wiped with the mixture. Zinc powder mixed with 5 percent to 10 percent sulfuric acid to form a paste can be spread over the contaminated area and allowed to dry. Both chemicals concentrate the mercury to facilitate its removal.
 - After the materials have been removed, check the area for the presence of mercury using a mercury sniffer.
 - Several cleanings may be necessary to remove all of the mercury.
3. Concentrated acids/bases
 - Wear heavy gloves that are acid resistant, goggles, and body protection (lab coat or rubber apron).
 - Take care not to step on the spilled materials.
 - Absorb the spill using acid or base Spill-X or absorbent pillows.
 - Products designed to neutralize acids or bases can produce large amounts of heat and may splatter. Treat the spill in small sections.

- Sweep or scoop the neutralized materials into bags and dispose of in the trash (if neutralized).
 - Clean area thoroughly with soap and water; dry thoroughly.
4. Flammable/volatile chemicals
- Immediately extinguish all open flames.
 - Shut down all sources of ignition (sparking equipment, incubators, flame AA, etc.).
 - Remember, for extremely explosive gases, the spark from turning on a light switch can be sufficient to ignite the gas.
 - Vapors can travel from open containers or other sources of volatile chemicals. Ethanol, methanol, propanol, and acetone, for example, should be isolated within a fume hood when in an open container. Special flammable storage cabinets should be used to store these materials.
 - Alert other workers present in the lab of the situation and seek assistance if necessary.
 - Open any windows/doors and the fume hood sash to help dissipate vapor.
 - Absorb the spill using spill-control pillows or other absorbent materials designed for volatile agents.
 - Place the saturated pillow or absorbent materials into a plastic bag (hazwaste bag) and place the bag into a fume hood or outside the main laboratory, if possible.
 - Use gloves and shovels, scoops, or brooms to move the material. (All materials used to transport the spilled substance must be decontaminated or, if not possible to decontaminate, disposed of together with the hazardous substance, as with mercury.)
 - Return to the site and, after the remaining material has evaporated, clean up the contaminated area using soap and water if possible.
 - If cleanup procedures are in doubt, mark the contaminated area with a warning sign and isolate with hazard tape, cones, or other type barricade material. Immediately report the spill to the lab supervisor.

Exposure to Chemicals

1. If a chemical comes in contact with unprotected hand(s), wash hands immediately using warm water and a strong soap such as dishwashing detergent. *Do not use* alcohol, acetone, or other solvents (these will facilitate absorption of the chemical through the skin).
2. Splashes into eyes, nose, or lip area must be removed immediately using an eyewash station/hose or by placing face under a steady stream of lukewarm running water. A mild soap may be used for the lips and nose, but only running water is to be used for the eyes. It is important that the eyes be held open in the stream of water and that contact lenses be removed to facilitate cleansing of the eyes. Roll the affected eye during the rinsing, which should continue for at least 15 minutes. Seek medical attention immediately.
3. If a chemical has been spilled onto clothing or other parts of the body, remove any contaminated clothing or jewelry immediately and wash the body part with warm

water and soap for at least ten minutes. Contact with phenol, DMSO-containing solutions, cyanate, or pyridine is especially serious, since these compounds pass through the skin and into the bloodstream rapidly. Dispose of the contaminated clothing in the same manner that the chemical wastes are treated. Seek medical attention.

4. If a toxic substance is spilled and inhaled, the substance is absorbed quite rapidly into the bloodstream. Those personnel exposed in such a manner should leave the contaminated area and seek immediate medical attention.

Attempt to cough up as much bodily secretions as possible and rinse mouth with water. Remove stunned or unconscious victims from the contaminated area only with the use of SCBA (self-contained breathing apparatus). Never attempt to remove a victim from a room containing toxic vapors without using protective breathing apparatus. Be cautious about using CPR on a person who has inhaled toxic vapors, in order not to inhale any of the poison from the victim. Administer emergency oxygen, if trained to do so. Place warning signs at the room entrance where the accident occurred to indicate contaminated area.

5. If materials have been ingested, rinse mouth with warm water repeatedly. If corrosives were ingested, do not attempt to neutralize the chemical, since this will only generate heat that may further damage sensitive tissues. Most physicians recommend diluting the corrosive materials using large quantities of water or milk. Do not attempt to induce vomiting if corrosives have been swallowed, since this may rupture the esophagus. If other toxic substances have been swallowed, drink large amounts of water or milk to dilute the toxin. Vomiting may be induced only if corrosives or hydrocarbons (petroleum distillates) have not been swallowed. Seek medical attention and be prepared to inform the medical authorities about the nature and approximate amount of chemical that was ingested.

Preventing Fires

Note: A fire may be prevented or stopped by removing any of the three necessary elements: fuel, oxygen, and ignition source.

1. Restrict the fuel by using only minimal amounts of flammable materials in the work area. Large containers of flammable solvents or other chemicals should be kept in an approved safety cabinet with doors closed.
2. Limit access to oxygen by keeping all containers capped when not in use. Especially with volatile solvents, it is important to ensure that the containers are closed immediately after dispensing the necessary amounts. Remove the working container from the work area after it is no longer needed.
3. Keep ignition sources away from available fuels. Although it should be obvious that an ignition source never should be near combustible materials, it is often overlooked. It may not be uncommon to use solvents in close proximity to electrically powered equipment such as stirrers, ultrasonic baths, or even ovens. Since solvent vapors may travel some distance, a spark or heating coil may ignite the vapor phase, which may then serve as a conduit back to the fluid phase. One should never store

solvents in a standard refrigerator, since a spark from the thermostat, compressor, or other electrical relays may cause an explosion. Instead, a specially designed explosion-proof or flammables refrigerator may be used to store volatile chemicals. Self-defrosting refrigerators cannot be safely modified to store volatile materials.

Note: Care must be taken to ensure that no open solvents are left near the high-temperature ovens.

Stopping Fires

1. Evacuate all persons to a safe location. Evacuation is *always* to an upwind direction of fire or chemical spill. Note the wind direction and assemble in the designated mustering location on the side of the environmental laboratory building that is upwind. If the upwind side is the street, gather directly across the street. Everyone must gather at the pre-arranged assembly point (this is important in order to determine if anyone is still in the building). The chemist for each section will perform a head count to assure that all technicians working that day are safe. If the chemist is not present, the senior technician in the section will count those present. If anyone is injured, do not attempt to move him or her unless the fire appears to be out of control.
2. If it is possible to extinguish the fire safely, do so immediately. After determining the type of fire, select the proper fire extinguisher and position yourself between the fire and the room exit. Do not permit the fire to block your exit. After the fire is safely out, notify the fire department so that it may evaluate the need for further measures.
3. If it is not possible to quickly extinguish the fire, close off the room and activate the fire alarm to alert others in the building. Telephone the fire department, giving the exact location of the fire. Indicate the nature of the fire (electrical, chemical, flammable liquids, etc.) and if hazardous materials are involved. Proceed to the assembly point and be prepared to meet the fire department with further directions as needed.

Classes of Fires and Proper Extinguishers

1. **Class A fires:** This is the most common type of fire; wood, cloth, paper, or other common combustibles are involved. This type of fire is best extinguished with a pressurized tank usually containing either plain water or water in combination with special wetting agents and aqueous film-forming foam (AFFF). This type of extinguisher is often found in corridors and in offices. A special fire blanket may also be used.
2. **Class B fires:** Flammable liquids are involved. These fires are extinguished by using pressurized carbon dioxide, halogenated compounds such as Halon, dry chemicals (ammonium phosphate, sodium/potassium bicarbonates, potassium chloride), or possibly by means of AFFF.

3. **Class C fires:** Live electrical circuits are involved either as the cause of the fire or as simply being near the fire. Use carbon dioxide, Halon, or dry chemical extinguishers. Aqueous-based or electrically conductive reagents must not be used to fight such fires.
4. **Class D fires:** Combustible metals such as magnesium, sodium, or potassium are involved. Class D fire extinguishers contain dry chemicals such as sodium chloride containing a thermoplastic binder that forms a solid suffocating crust over the fire. None of the common extinguishers should be used, since they can increase the intensity of the fire by adding an additional chemical reaction.

Using Fire Extinguishers

Although fire is generally a panic situation, try not to panic—when panic sets in, mistakes are made and a bad situation turns worse, usually in an exponential fashion. To fight the fire, direct the spray at the base of the fire, not at the flames. The object is to suffocate and cool the chain reaction that is occurring at the level of the fuel. Slowly sweep the extinguishing agent over the base of the fire until all flames are extinguished. Even after the flames have subsided, continue to apply the agent to prevent a flare-up or flashback of the fire.

Note: The following hazards/hazard categories/procedures may or may not be related to emergency response in the laboratory; however, each of these hazards is important to consider in any laboratory safety program. Lab technicians and other lab personnel need to be thoroughly aware and familiar with the subject areas that follow.

Electrical Safety

1. Keep electrical equipment away from lab sinks and running water. In addition, wet floors should be mopped, not only to prevent a slip hazard but also to prevent electrical shock. A rubber mat provides some protection against electrical shock, but should not be depended on as a substitute for proper grounding and bonding of electrical equipment and maintaining floors in a dry condition.
2. Check electrical cords for fraying; never allow them to dangle over sinks. Report damaged cords to the electricians immediately, and label the equipment (tag it out) so that it will not be used.
3. Any electrical equipment that must be near a sink must be secured in place and isolated from splash or spray.
4. Outlets on the backsplash of a sink must be equipped with a ground-fault circuit interrupter (GFCI). Rubber mats should be placed in front of sinks that have electrical outlets on the backsplash.
5. Do not handle electrical equipment with wet hands. Keep areas surrounding sinks dry. Do not touch an electrical device and the sink, faucet, or water at the same time. Do not reach into a sink to retrieve an electrical item that has dropped in. Either unplug the item or cut off the circuit breaker (safest) and then unplug, before

retrieving. Label such equipment for evaluation by the electrician before using it again.

6. Equipment that generates or uses large amounts of current or magnetic fields should only be operated by properly trained individuals, following the manufacturer's recommendations.
7. Always unplug equipment when cleaning or servicing.
8. All electrical equipment should use a three-prong or other properly grounded connector. Do not use two-to-three-prong adapters without ascertaining that a proper ground has been established (check with an electrician). Determine the location and how to use circuit breakers or fuse boards to cut off the power to equipment in an emergency.
9. Servicing of electrical equipment should be left to qualified personnel only. Disconnect the equipment, tag it out, and notify the supervisor.

First Aid for Shock Victims

If contact with a live electrical circuit has taken place, the first step should be to cut off the current at the circuit breaker box. If this is not possible, separate the victim from the electrical source using a nonconductive material such as a lab coat, wooden chair, or rubber hose. Make sure that you do not become involved in the circuit (avoid water spills or making contact with grounded objects such as water faucets or other electrical equipment). If the victim is unconscious, attempt to arouse him or her by gentle shaking. If breathing has stopped or a pulse cannot be felt, apply cardiopulmonary resuscitation (CPR) following approved methods. Send someone to call for medical help.

Physical and Mechanical Hazards

1. Sharp objects
 - Keep glass shards or cracked glass vessels in a thick-walled box lined with a plastic bag. When filled, tape the box shut and dispose of in the appropriate manner.
2. Vacuum pumps
 - Pumps become very hot during operation. Be cautious of burn hazards.
 - Used pump oil should be disposed of in the same fashion as other used oil products, except when the pump has been used to vacuum aspirate toxic or carcinogenic substances. Used oil from these pumps is hazardous waste and must be disposed of accordingly. This kind of pump should not be vented into the work area. Exhaust the pump into a fume hood or outside the building.
3. Ovens
 - Never place volatile organic solvents such as acetone, alcohol, toluene, and so on, into an oven. Vent ovens to fume hoods.
4. Cryogenic gases
 - Frostbite hazard exists when working with gases such as liquid helium, nitrogen, and carbon dioxide, resulting in serious burns. Use insulated gloves and a face shield when dispensing cryogenics. Sandals or open-toed footwear must not be

worn. Nonabsorbent laboratory clothing is recommended. If liquid cryogens are spilled onto ordinary laboratory clothing, the clothing must be removed as rapidly as possible, since it may freeze onto the skin.

- If liquid carbon dioxide is to be used, take care that the dry ice does not block the outlets and gas lines.
- Cryogens should not be used in confined spaces, where accidental release will displace oxygen.

Compressed Gas Safety

The very properties that make compressed gases, liquefied compressed gases, and cryogenic liquids useful in almost every area of modern life can also make them dangerous when mishandled (Compressed Gas Association 1990).

“Dangerous when mishandled” is the key phrase. Fortunately, years of experience with compressed gas has resulted in safe work practices and equipment that, if properly used, results in complete safety.

Compressed gases are usually stored in cylinders or other containers at high pressures and must always be handled with care. While compressed gas containers are designed to meet rigid regulatory specifications and are safe for their intended use, they can be extremely hazardous if abused or misused. Thus, care and caution is always advised when working with or around compressed gases.

Compressed gas cylinder description: A compressed gas cylinder may have a series of numbers stamped into it. For instance, the designation “DOT 3AA 2300” refers to Department of Transportation (DOT) specification of tank for 2,300 psi at 70°F. Directly under this designation may be a serial number such as “Z48976” to identify the specific tank. Other identifiers, such as “10 PB 89+,” indicate the most recent inspection date or date of manufacture. In this case, an inspector with initials PB inspected the cylinder in October 1989. The plus sign reveals that this tank may be filled to 10 percent over the 2,300 psi service pressure. In addition, the tank must be clearly marked as to the contents and whether or not the gas is hazardous.

All compressed gas cylinders are equipped with a safety device that permit gas to escape from the cylinder in the event that excessive pressures develop inside the tank. A hand wheel is used to open or close the valve, but not to adjust the pressure of the escaping gas. An outlet connection is provided for attaching a pressure regulator valve to the main cylinder valve. The threads of these connections are designed to accommodate special regulators or attachments and to prevent the connection of improper accessories to the tank (e.g., the wrong type of regulator). A two-stage pressure regulator valve is normally used with the standard compressed gas cylinder. The gauge nearest the cylinder indicates the pressure inside the main tank, while the second gauge indicates the discharge pressure of the gas. The discharge pressure is regulated by the handle on the large portion of the regulator. In most of these valves, the discharge pressure may be increased by turning the valve clockwise, rather than counterclockwise as one might expect. A final delivery valve may be present to turn the flow of gas from the regulator on or off. It has no effect on the dispensing pressure, but only on the rate

of discharge. All tanks have a cylinder cap that is screwed over the cylinder valve to protect it when the tank is not in use or during shipping. *This cap must be securely screwed in place on all tanks that do not have a regulator or on tanks that are not in use.*

Compressed gas cylinder operation: When received, a cylinder must be checked for damage and for proper contents. An in-house “necklace” label should be placed over the cap of the tank to indicate its contents, that it is full, the date received, and the initials of the person receiving the tank.

Caution: The Compressed Gas Association warns that color should never be used as the sole means of identifying the contents of a compressed gas container.

Do not attempt to open the main tank valve until the tank has been attached to a pressure regulator or other piece of equipment. Otherwise, the tank may give off a high pressure discharge of gas that cuts like a knife.

Caution: The Compressed Gas Association warns that the release of high pressure gas from cylinders can be hazardous unless adequate means are provided for reducing the gas pressure to usable levels and for controlling the gas flow. Accordingly, pressure-reducing regulators should always be used when withdrawing the contents of a cylinder, as such devices deliver a constant safe working pressure.

Transport the cylinder in a specially designed gas tank transport cart with the cap in place and with the tank secured to the cart with chains or ties. Never attempt to move the cylinder by rolling it or sliding it along the floor as it may drop to the floor and damage the main cylinder valve.

Store gas cylinders in a dry, well-ventilated area that does not get excessively hot or cold (-29°C to 52°C). Do not store incompatible gases in close proximity.

Cylinders must be securely chained or held in place to prevent their falling over. When removing tanks, use the special cart to transport them to the location and immediately chain or secure the tank into position rather than leaving it on the cart.

When attaching the cylinder to the apparatus or pressure regulator, use the proper tool (wrench) rather than a makeshift device such as pliers. Keep the proper tool chained near the area where the cylinder is used. The apparatus should be securely attached to the main valve so that it will not shift position when lateral pressure is applied to the device. After attaching the device to the main cylinder valve and before opening it, verify that the attached device or pressure regulator is closed off. Then partially open the main cylinder valve and check for any leaks between the main valve and the attached device. If any leaks are found, close the main valve immediately and seek assistance from the workplace supervisor. If no leaks are found, check the tank pressure (it should be neither too high nor too low for the particular gas) and verify that the discharge pressure valve is closed or that the final dispensing valve is closed.

Adjust the flow of gas using the pressure adjustment valve (if present) and open the final valve. If any problems are encountered during the use of the compressed gas, turn off the main tank valve first before attempting to resolve the problem. Wear appropriate eye, hand, and body protection when working with the cylinders and use no lubricants on the cylinder or the pressure regulators. It is best to discontinue using the

tank before it is completely empty to prevent contaminants from entering the tank during the refilling step at the suppliers. Remove the original necklace label and replace it with another label indicating that the cylinder is empty. Have the empty tank removed as soon as possible to prevent others from using it and to remove clutter from the laboratory. The tank must be transported back to storage on the cylinder cart with the cylinder cap in place.

Caution: The Compressed Gas Association warns: Do not attempt to force connections that do not fit.

General safety considerations for compressed gases: The Compressed Gas Association advises or cautions about a number of practices (in addition to those already pointed out above) that should be followed or avoided when handling compressed gas cylinders. These advisories are listed in the following:

1. **Caution:** Compressed gases must never be transferred from one container to another except by the gas manufacturer or distributor.
2. **Caution:** Do not smoke or permit smoking or open flames in any area where flammable liquids or gases or liquid oxygen are stored, handled, or used, or where they are loaded or unloaded.
3. **Caution:** Keep all combustible materials, especially oil or grease, away from oxygen.
4. **Caution:** Liquid oxygen, if spilled on clothing or another combustible substance, can pose a serious hazard of fire or explosion due to the rapid chemical reaction between the two substances.
5. **Caution:** A flame must never be used for detection of flammable gas leaks.
6. **Caution:** Never permit oil, grease, or other combustible materials to come in contact with cylinders, valves, regulators, gases, hose, and fittings used for oxidizing gases such as oxygen and nitrous oxide, which may combine with these substances with explosive violence.
7. **Caution:** Poison gases pose serious potential hazards to personnel and therefore require special handling.
8. **Caution:** Corrosive gases attack human tissue and other materials, and special protective clothing and self-contained breathing apparatus must be used by personnel handling these substances.

Centrifuge Safety

1. Before using a centrifuge check to ensure that it is in proper operating condition, check the log book and review any notes from previous users.
2. Make certain that the proper rotor is being used—that it is rated for the speeds to be used.
3. Verify that the centrifuge tubes to be used are proper for the rotor and that they can withstand the g forces that will be generated and the chemicals that will be placed in them.

4. Stand clear of the rotor as it is accelerating or slowing down. Take care to keep long hair or jewelry away from the spinning rotor.
5. Never stop or slow a rotor with the hand. Clean up spills inside the centrifuge and especially in the rotor.
6. Note any unusual noises or operational problems in a log book.

Pipetting Safety

1. The use of mouth pipetting is strictly prohibited in all chemical workplaces. The danger of ingesting toxic liquids or vapors from the liquids is simply too great to risk such a procedure.
2. Never point a pipette in the direction of another person.
3. Broken or chipped glass pipettes are to be disposed of in designated broken glass containers.

Fall Prevention

1. Keep workplace aisles clear and floors dry.
2. Use approved ladders or stepstools for reaching upper shelves.

Medical Emergency

Along with providing a written plan, emergency equipment, and worker training for chemical/hazardous materials incidents in the environmental laboratory, it is also important to include medical response planning and training. The lab's medical response plan should be integrated with the emergency action plan or procedures.

In addition to having some type of medical response plan, it is also important that the chemical industry workplace establish emergency first-aid stations. These first-aid stations should be stocked with enough medical supplies to provide general first aid for minor cuts, sprains, and abrasions. In addition to standard first-aid supplies, these first-aid stations should contain stretchers, burn kits, ice, emergency eyewash, and fire extinguishing blankets. Emergency medical phone numbers should be posted throughout the laboratory at, near, or on each phone.

As with all types of emergency response, training and regulatory compliance are the key elements. One thing is certain, when hazardous materials/chemicals are involved with any type of emergency response, the responders must be trained to know how to prevent spread of the spill and how to protect themselves from contamination. In addition, key chemical industry workplace personnel should be trained in standard first aid—all workers should be trained in CPR. Finally, in order to ensure good first aid and emergency medical practices, the employer must ensure compliance with OSHA's 29 CFR 1910.151 (Medical Services and First Aid).

Summary of Chemical Workers' Safe Work Practices

1. Use care and caution when working with chemicals.
2. Store chemicals in a safe place where they are not hazardous to personnel or property.
3. Label all chemical containers, indicating the chemical name and date of preparation and/or container opening.
4. Check the labels on chemical containers before using to ensure that the proper chemicals are selected for use.
5. Properly dispose of unlabeled or out-of-date chemicals. *Never* dispose of chemicals in common trash containers. When hazardous waste is to be disposed, contact the workplace supervisor to ensure that proper disposal procedures are followed.
6. Read and learn the directions for each chemical's use and safety. This information is found on the chemical's MSDS.
7. Follow directions carefully. *Never* mix chemicals randomly or indiscriminately.
8. Handle chemicals carefully when pouring or measuring to prevent spillage.
9. Immediately clean up chemical spills according to the directions on the chemical's MSDS.
10. Avoid personal contact with chemicals.
11. Wear correct gloves (see appendix A) for the chemical being handled. Refer to the chemical's MSDS if unsure about proper hand protection. *Never* touch chemicals with bare hands.
12. Ensure that protective gloves (see appendix A) are free of cracks, tears, and holes and that gloves fit properly before handling chemicals.
13. Do not place fingers into mouth, nose, ears, or eyes while handling chemicals.
14. Wash hands with a disinfectant soap after handling chemicals.
15. Wash off chemical spills on skin immediately with running water.
16. Do not smoke or eat in the workplace while handling chemicals.
17. Avoid breathing chemical vapors, dusts, or fumes.
18. Provide positive ventilation to chemical work areas.
19. Properly dispose of all broken, chipped, or cracked glassware.
20. Do not use chemical glassware as coffee cups or food containers.
21. Use a suction bulb to pipette chemicals. *Never* use mouth to suck up a fluid or chemical in a pipette.
22. As required by the applicable MSDS, use safety goggles and/or face shield when transferring and measuring chemicals, or whenever there is a potential for chemicals to be splashed in the eyes.
23. Use tongs or thermal gloves when handling hot utensils.
24. Use only properly grounded electrical equipment.
25. Always *add acid to water*, *not* water to acid.
26. Use carbon dioxide or dry chemical-type fire extinguishers to control chemical fires.

27. Ensure that the work center is equipped with a properly working emergency eye-wash/shower. Chemical workers should anticipate the need to use emergency eye-wash/showers and be familiar with the quickest route to each eyewash/shower station in close proximity to their work station.
28. Ensure that prominent signs warning workers against hot areas such as vents, hot plates, furnaces, water baths, and digestion apparatus are posted in the work area.
29. Inspect acid-neutralizing tanks and basins that service lab sinks regularly and recharge with correct neutralizing agent when needed.
30. Ensure that emergency phone numbers are posted by all telephones.

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APPENDIX

Chemical Guide A-X

NFPA 704					DOT/EPA			Gloves—Breakthrough Time (Min)			
Chemical	Fire	Health	Reactivity	Other	DOT Class	Waste Codes	Category	4-H/Silver			
								Nitrile	Shield	Neoprene	Latex
Acetaldehyde	4	2	2	N	3	U001, D001	A	<0.6	>360	10.2	7
Acetic Acid	2	2	0	N	8	D002	Co-Ac	5	>480	360	21
Acetic Anhydride	2	2	1	N	8	D002	Co		>480	210	3
Acetone	3	1	0		3	U002, F003, D001	A	3	>1440	2.4	2.4
Acetonitrile (Methyl Cyanide)	3	3	0	N	3	D001	B	<5	>1440	<10.8	<0.6
Acetophenone	2	1	0	N		U004	A		>480		
Acetyl Chloride	3	3	2	WR	3	U006, D001, D002, D003	F1				
Acrolein	3	3	3	N	6.1	P003, D001	F1	4.2	>480		
Acrylamide	2	3	2	N	6.1	U007	P		>240		
Acrylic Acid	2	3	2	N	8	U008, D001	F1		>240	70	80
Acrylonitrile	3	4	2	N	3	U009, D001	F1	<5	>480		
Aldehyde					3	D001	A	4	>360		
Allyl Alcohol	3	3	1	N	6.1	P005	F1			94.8	
Allylamine	3	3	1	N	6.1	D001	F1		15		<1.2
Allyl Chloride	3	3	1	N	3	D001	F1		>240		
Ammonia	1	3	0	N	2.3	D002	Co-Ba		110		
Ammonium Fluoride					6.1		Co	>360	>240	>360	>360
Ammonium Hydroxide					2.3	D002	Co-Ba	360	360	360	90
Amyl Acetate (Isoamyl Acetate)	3	1	0	N	3	D001	A	<5		5.4	5.4

Amyl Alcohol	3	1	0	N	3	D001	A	30	321	7.2
Amyl Nitrite	2	2	0	Ox	3			175.8	46.8	
Aniline	2	3	0	N	6.1	U012	B	18	>1440	25
Benomyl						U271	P		>240	
Benzaldehyde	2	2	0	N	9		A	<5	>480	10
Benzene	3	2	0	N	3	U019, D001, F005, D018	A	4.2	480	0.6
Benzenesulfonic Acid							NR	>240	>1200	
Benzethonium Chloride							NR		>480	>480
Benzonitrile (Phenyl Cyanide)					6.1		NR		<0.6	>480
Benzophenone Tetracarboxylic Dianhydride							NR		>240	
Benzoyl Chloride	2	3	2	WR	8		F1		15	
Benzyl Alcohol	1	2	0	N			A		>480	
Benzyl Cyanide	1	2	0	N			F1		>240	
Benzyl- dimethylamine (Dimethyl- benzylamine)							F1		>240	
Bisphenol- diglycidyl Ether	2	2	0	N	8				>480	
Bisphthalate								259.8	120	>360
Boric Acid							NR	>480	>480	

Note: See key on page 189.

Butyl Hydroperoxide	4	1	4	Ox	N	D001, D003	OP	>240
Butyl Nitrite	3	1	3	N	3	D001, D003	OP	97.8
Butyltoluene					6.1		A	>360
Butyraldehyde	3	2	2	N	3	D001	A	>480
Butyrolactone	1	0	0	N			A	>480
Carbon Disulfide	4	2	0	N	3	P022, D001 F005	FI	1
Carbon Tetrachloride	0	3	0	N	6.1	U211, D019	C	5
Cellosolve (Ethoxyethanol)						D001, F005 U359	A	25
Cellosolve Acetate (Ethoxyethyl Acetate)						D001	A	<5
Chlorine	0	3	0	Ox	2.3		Hood	>240
Chloroacetic Acid	1	3	0	N	6.1	D001	Co-Ac	
Chloroacetone					6.1	D001	FI	>240
Chloroacetonitrile								<0.6
Chloroaniline					6.1		C	
Chlorobenzene	3	2	0	N	3	U037, D021, D001, F002	C	<5
Chlorobutadiene (Chlorophrene)	3	2	0	N		D001	C	3
Chloroethanol (Ethylene Chlorohydrin)	2	3	0	N	6.1	D001	Hood	>240
Chloroform	0	2	0	N	6.1	U044, D022	C	2.4
Chloromethyl Methyl Ether						U046	FI	0.6

NFPA 704					DOT/EPA		Gloves—Breakthrough Time (Min)			
Chemical	Fire	Health	Reactivity	Other	DOT		Category	4-H/Silver		Latex
					Class	Waste Codes		Nitrile	Shield	
Chloronaphthalene	1	1	0	N	U047	F	174	>480		<5
Chloronitropropane										1.2
Chloropropanol										<0.6
Chloropropene	4	2	2	N	3	D001	C	>240		
Chlorosulfonic Acid	0	3	2	WR	8		NR			
Chlorotoluene (Benzyl Chloride)	2	2	1	N	3	P028	F1	15	>480	
Chromic Acid	0	3	1	Ox	8	D001, D002 D007	Ox	240	>240	75 70.2
Citric Acid						N	Keep			>360 >360
Cleaning Agent	2	0	0	N					>480	
Copper										>360
Creosol	2	2	0	N		U051	F1		>240	270
Creosote	2	3	0	N	6.1	U052	F1	<5	>240	>60 13.8
Crotonaldehyde	3	3	2	N	6.1	D001, U053	F1			21
Cyclohexane	3	1	0	N	3	U056, D001	A	360	>480	6 1.8
Cyclohexanol	2	1	0	N			A	360	>480	150 10
Cyclohexanone	2	1	0	N	3	U051, D001	A	<5	>480	
Cyclohexylimine	3	2	0	N	8	D001	B		>240	36 1.2
Cyclopentanone	3	2	0	N	3	D001	A		>240	
Cypermethrin							NR		>240	
Decanal (Decyl Aldehyde)							NR			240

Deep Woods Off (R)										>240
Diacetone Alcohol (Hydroxy Methyl Pentanone)	2	1	0	N	3	D001	A	>240	300	15
Diaminodiphenyl- methane (Methylene-dianiline)					6.1		NR	>1440		
Diamylamin	2	3	0	N		D001	B	>480		
Dibromoethane (Ethylene Dibromide)	0	3	0	N	6.1	U067	F1	>480	4.8	<1.2
Dibutylamine	2	3	0	N		D001	B	>480		
Dibutyl Ether (Butyl Ether)	3	2	1	N	3	D001	A	>480		
Dibutyl Phthalate (Butyl Phthalate)										
Dichloroaniline	1	3	0	N	6.1		NR			
Dichlorobenzene	2	2	0	N	6.1	D027, U072, F002, U070, U071	P	<5	>240	
Dichlorobutene										
Dichlorobutene					8	D001	C	2.4	>240	10.2
Dichloroethane (Ethylene Dichloride)										
Dichloroethane					3	D028, U076 D001, U077	C	2.4	144	1.8
Dichloroethylene	3	2	2	N	3	D001, D029 U078	C	7.2	>420	0.6
Dichloromethane										
Dichloropropene	3	3	0	N	3	D001	C	>480		
Diesel					3	D001	A	>240		

Chemical	NFPA 704				DOT/EPA			Gloves—Breakthrough Time (Min)			
	Fire	Health	Reactivity	Other	DOT Class	Waste Codes	Category	Nitrile	4-H/Silver Shield	Neoprene	Latex
Diethanolamine							B	>480	>240	>480	
Diethylacetamide							NR		>480		
Diethylamine	3	3	0	N	3	D001	B	<5	60		<5
Diethylamino-ethanol					3	D001	B	>480			
Diethylenedioxide (Dioxane)	3	2	1	N	3	D001, U108	A	<5	>480	6.4	2.4
Diethylenetriamine	1	3	0	N	8		B	>240	>240	>480	
Diethylnitrosoamine							NR		>240		
Diethylphthalate						U088	A		>240		
Diisobutylamine					3	D001	B	>480		52.2	
Diisobutyl Ketone					3	D001	A	120	>360	15	15
Diisopropylamine	3	3	0	N	3	D001	B	195		40.2	
Dimercaptothiodiazole								>240			
Dimethylacetamide							B	<5	>240		15
Dimethylamine	4	3	0	N	2.1	D001	Hood			>480	1.8
Dimethylamino-Propylamine						D001	B			28.8	0.6
Dimethylaniline					6.1		B		>240		
Dimethylbutylamine					3			81			
Dimethylcyclo-hexylamine					8	D001	B		>480		

[illegible]

Chemical	NFPA 704				DOT/EPA			Gloves—Breakthrough Time (Min)			
	Fire	Health	Reactivity	Other	DOT Class	Waste Codes	Category	Nitrile	4-H/Silver Shield	Neoprene	Latex
Epichlorohydrin	3	3	2	N	6.1	U041, D001	F1	19.8	>240	15	>1.2
Epoxybutane (Butylene Oxide)					3	D001	A			4.2	
Ethanol					3	D001	A	>240	>480	49.2	12
Ethanolamine					8		B	360	>480	360	210
Ether (Ethyl Ether Diethyl Ether)	4	2	1	N	3	U117, F003	A	13.8	>480	10	10.2
Ethidium Bromide							NR		>480		
Ethoxypropanol									>240		
Ethyl Acetate					3	U112, D001, F003	A	>5	>1440	12	4.8
Ethyl Acrylate	3	2	2	N	3	U113, D001	F1		>240	48	
Ethylamine					2.1	D001	B	66	28.2		
Ethylbenzene	3	2	0	N	3	F003, D001	A	<5	>480		
Ethylbromide					6.1	D001	C			4.2	
Ethylbutylamine						D001	B			73.2	
Ethyl Cellosolve (Ethoxyethanol)								91.8	<240	244.8	<0.6
Ethyl Cellosolve Acetate											
Ethyl Cyanide											<0.6
Ethylenediamine	3	3	0	N		D001	B		92	399	4.8
Ethylene Glycol							A	360	>240	360	360

Ethyleneimine				6.1	P054; D001	F1	<4.8
Ethylene Oxide	4	2	3	N	U115, D001	F1	>240
Ethylglycol							>240
Ethylglycol Acetate							>240
Ethylglycol Ether							45 25
Ethylhexanoic Acid						NR >240	>240
Ethylhexanol						A	>480
Ethyl Methacrylate					U118, D001	F1 22.8	
Fluorobenzene			3	D001	C		
Fluoroboric Acid	0	3	0	N	D002 Co-Ac		>240
Formaldehyde	4	3	0	N	U122 A	>1260	120 120
Formic Acid	2	3	0	N	D002 C0-Ac	5	120 >360 120
Freon (Dichlorodifluoro- Methane)				2.2	U075	C	10.2 >240 3 2.4
Furaldehyde (Furfural)	2	2	0	N	D001, U125	F1	<5 >480 19.8 15
Furfuryl Alcohol				6.1	D001	A	>480
Gasohol				3	D001	A	
Gasoline				3	D001	A	30 >240 <5
Glutaraldehyde						A	>240 >480
Glycerol (Glycerin)						NR	>240
Glycerolmonoethio- glycolate							>240
Glycerolpropoxy- propylamine							>240

Chemical	NFPA 704					DOT/EPA			Gloves—Breakthrough Time (Min)			
	Fire	Health	Reactivity	Other	DOT Class	Waste Codes	Category	Nitrile	4-H/Silver Shield			Latex
Glycerolpropoxy-triacrylate					3	D001	A	360	>480	45	1.2	
Heptane					3	D001	A	360	>480	45	1.2	
Hexachloro-cyclopentadiene					6.1	U130	F1	>480				
Hexamethyl-disilazane	3	2	1	N		D001	F1		>240	50	15	
Hexamethylene Diisocyanate					6.1		F1					
Hexamethyl-phosphoramide							NR	90				
Hexane					3	D001	A	78.6	>1440	3.6	4.8	
Hydraulic Fluid						N	MP	>240	>480		<5	
Hydrazine	3	3	3	N	8	U133, D001	F1	>480	126	>960	150	
Hydrochloric Acid (Muriatic Acid)					8	D002	Co-Ac	360	>360	360	290	
Hydrocyanic Acid (Hydrogen Cyanide)	4	4	2	N	6.1	P063	Hood		>240			
Hydrofluoric Acid					8	U134, D002	Co-Ac	120	15	60	90	
Hydrogen Chloride	0	3	0	N	2.3	D002	Hood					
Hydrogen Peroxide	0	2	3	Ox	5.1	D001	Ox	>360	>240	4.8	>480	
Hydrogen Phosphide						P096	Hood			10.2	30	
Hydroquinone					6.1		NR	>360	>240	>360	>360	

Hydroxyethyl- acrylate						>240
Hydroxyethyl- trimethylammonium Hydroxide						>240
Hydro- xymethacrylate						>240
Imino- bipropylamine	B					>480
Isophorone	2	2	0	N		>240
Isoprene	4	2	2	N	3	52.2
Jet Fuel	3					D001
Kerosene	3					D001
Lactic Acid						D002
Lauric Acid						D001
Limonene						D001
Lubrication Oil						N
Malathion						MP
Maleic Acid	1	3	1	N	8	NR
Mercaptoethanol						D001
Mercuric Chloride						D009
Mercury						8
Methacrylic Acid	2	3	2	N	8	NR
Methacrylonitrile						3
Methanesulfonic Acid						D002

Methylenedisocyanate					NIR	>480
Methylene Dichloride (Methylene Chloride)	1	2	0	N	F002, U080	114 0.6
Methylethanamine					B	>480
Methyl Ethyl Ketone	3				D035, D001, F005, U159	2.4 1.2
Methyl Ethyl ketone Peroxide				N	U160, D001 D003	240 45
Methylethyl-ketoxime						
Methyl Glycol Ether						25 20
Methylhexanone (Methyl Isoamyl Ketone)	3				D001	<5 >480
Methyl Iodide	6.1				C	0.6 123 0.6 1.8
Methyl Isobutyl Ketone	3				U061, D001, F003	A 12 6
Methyl Isocyanate	6.1				P064, D001	F1 0.6 0.6
Methyl Mercaptan	2.3				U153, D001	Hood
Methyl Methacrylate	3	2	2	N	D001, U062	F1 <5 >480 <1.2
Methyl Norbornene Dicarboxylic Anhydride (Methylenetetracarboxylic Anhydride)	8					NIR >240
Methyl Pentyl Ketone						>240

Chemical	NFPA 704				DOT/EPA			Gloves—Breakthrough Time (Min)			
	Fire	Health	Reactivity	Other	DOT Class	Waste Codes	Category	Nitrile	4-H/Silver Shield	Neoprene	Latex
Methylpyrrolidone							B	<5	>240		75
Methyltrichlorosilane	3	3	2	WR	3	D001	F1		>240		
Mineral Oil						N	MP	>240			
Mineral Spirits						D001	A	>360		90	<5
Monoethanolamine	2	2	0	N	8			360	>480	360	50
Monoethylamine	4	3	0	N	2.1			66	28.2		
Morpholine	3	2	0	N	3	D002	B	<5	>480		20
Mustard Gas (Dichlorodiethyl Sulfide)							P		>240		
Naphthalene	2	2	0	N	4.1	U165	F1		>240		
Naphtha					3	D001	A	>360	>480	15	<5
Naphthylamine					6.1	U167, U168	P		>240		
Nickel										>360	
Nicotine					6.1	P075	P		>240		
Ninhydrin							NR		>240		
Nitric Acid	0	3	1	Ox	8	D002, D001	Co-Ac	5	34.8	79.8	<5
Nitrobenzene	2	3	1	N	6.1	F004, D036	B	<5	>1440	40.2	4.8
Nitrodiphenylamine							NR		>240		
Nitroethane	3	1	3	N	3	D001	B		>480	49.2	1.8
Nitrogen Tetroxide					2.3	D002 Ox					
Nitroglycerol (Nitroglycerin)					1.1	P081, D003	Ex		>240		

Nitroglycol											>240
Nitrohydrochloric Acid (Aqua-Regia)											
						8	D002	Co-Ac		45	<5
Nitromethane	3	1	4	N	3		D001	B	30	>480	60
Nitropropane	3	1	2	N	3		U171, D001	F1	12	>480	5
Nonylphenol											>1200
Octane (Isoctane)					3		D001	A	360		60
Octanol								A	360		360
Oleic Acid								NR	360		60
Ortho Toluidin											>480
Osmium Tetroxide					6.1		P087	Hood			
Oxalic Acid	1	2	0	N				NR	360	>480	360
Palmitic Acid								NR	30	>360	4.8
Parathion					6.1		P089	P		>240	
Pentachlorophenol	0	3	0	N	6.1		F027	P	>780	>480	6
Pentane					3		D001	A	1.8	>480	6.6
Pentylalcohol											176
Perchloric Acid	0	3	3	Ox	5.1		D001, D002	Ox	360	>240	360
Perchloroethylene					6.1					>480	<5
Petroleum Ether							D001	A	>240	>480	
Phenol	2	3	0	N	6.1		U188	A	31.8	130	40.2
Phenolphthalein								NR	>480		>480
Phosphoric Acid	0	3	0	N	8		D002	Co-Ac	360	>240	360
Phosphorous Oxchloride	0	3	2	WR	8		D002, D003	Co		>240	>0.6

NFPA 704					DOT/EPA			Gloves—Breakthrough Time (Min)			
Chemical	Fire	Health	Reactivity	Other	DOT		Waste Codes	Category	4-H/Silver		
					Class	8			Nitrile	Shield	Latex
Phosphorus Trichloride	0	3	2	WR	8		D002, D003	Co			
Phthalic Acid					8			NR		>240	
Picoly Chloride Hydrochloride										>240	
Picric Acid	4	3	4	N	1.1		D001	F1		150	<5
Polychlorinated Biphenyl	1	2	0	N	9		PCB1 PCB, PCB2	P		>480 1440	4.8
Polyethylene Glycol								NR		>480	
Polyol								NR		>480	
Potassium Acetate								NR			
Potassium Chromate							D001, D007	Ox			
Potassium Hydroxide	0	3	1	N	8		D002	C0-Ba	360	>240	180
Potassium Permanganate					5.1		D001	Ox		>240	
Promethazine Hydrochloride								NR	>480		
Propanol (isopropanol)					3		D001	A	30	>480	90
Propanolamine (Monoiso-Propanolamine)										>480	30
Propiolactone											19.8
Propionaldehyde	3	2	2	N	3		D001	A		12	
Propiophenone								A		>240	
Propylacetate					3		D001	A	16.8	>480	4.8

Propylamine	3	3	0	N	3	U194, D001	B	13.8
Propylenediamine (Diaminopropane)	3	2	0	N		D001	B	271.9 3
Propyleneglycol							NR >240	>360
Propyleneglycol- monoethylether- acetate							>240	
Propylene Oxide	2	4	2	N	3	D001	A	>240 >0.6
Propyl Ether (Isopropyl Ether)							>60	42.6 3.6
Propylmethacrylate							60	
Propyl Nitrate	3	2	3	Ox		D001, D003	OP	>240
Propylamide							>240	
Pyridine	3	2	0	N		U196, F005, D038	B	5.4 >480 1.8 2.4
Pyrrolidine					3	D001 B		
Quinoline					6.1		NR	>240
Roundup (R) (Glycophase)							NR	>240
Rubber Solvent					3			30 <5
Silicon Etch								>360 <5
Silver Cyanide					6.1	D003, D011, P104	P-Cn	>240
Sodium Cyanide	0	3	0	N	6.1	D003, P106	P-Cn	
Sodium Hydroxide	0	3	1	N	8	D002	Co-Ba	360 >480 360
Sodium Hypochlorite					5.1	D001	Ox	360 >240 360

Chemical	NFPA 704				DOT/EPA			Gloves—Breakthrough Time (Min)			
	Fire	Health	Reactivity	Other	DOT Class	Waste Codes	Category	Nitrile	4-H/Silver		
									Shield	Neoprene	Latex
Stoddard Solvent	2	0	0	N		D001	A	>240		180	<5
Stripper									132		
Styrene	3	2	2	N	3	D001	F1	30	>1440	12	10.8
Sulfur Dioxide	0	3	0	N	2.3	D001	Ox				
Sulfuric Acid (Oleum)	0	3	2	WR	8	D002	Co-Ac	5	120	70.2	<5
Tannic acid							NR	>360		>360	>360
Tetrachloroethane					6.1	U208, U209	C	13.2		5.4	1.8
Tetrachloro- ethylene	0	2	0	N	6.1	D039 U210, F002	C	5	>1440	6	<1.2
Tetraethylene- pentamine					8		NR			>480	106
Tetraethylortho- silicate					3				>480		
Tetrafluoroboric Acid										>240	
Tetrafluoroethylene	4	2	3	N	2.1	D001	Hood			>480	
Tetrahydrofuran	3	2	1	N	3	D001, U213	A	0.6	>480	1.2	1.2
Tetramethyl- ammonium Hydroxide					8		NR			>240	
Tetramethylene- diamine							NR	108			
Thinner						D001	A		>240		

Thioglycolic Acid (Mercaptoacetic Acid)					8		D002	Hood	>240
Thiophene					3		D001	Hood	>360
Thiourea							U219	P	>240
Toluene	3	2	0	N	3		D001, F005, U220	A	<5 1.2 0.6
Toluene									
Toluenesulfonic Acid	1	3	2	N	6.1		U223	P	222 >480 7
Toluidine	2	3	0	N	6.1		U328, U053	P	NR >480
Transmission Oil							N	MP	>240
Triallylamine					3		D001	B	>480 63
Tributylphosphate								NR	>240
Trichloro- Acetonitrile								C	67.2
Trichlorobenzene					6.1			C	<5 60 4.8
Trichloroethane	1	3	0	N	6.1		U227, F002, U226	C	1.8 2.4 1.2
Trichloroethanol								C	
Trichloroethylene	2	2	0	N	6.1		U228, D040, F002	C	<5 >1440 1.8 0.6
Trichloropropane								C	21
Tricresylphosphate					6.1			NR	60 >360 45
Triethanolamine								B	>480 >240 >360 60

<i>Chemical</i>	<i>NFPA 704</i>				<i>DOT/EPA</i>			<i>Gloves—Breakthrough Time (Min)</i>			
	<i>Fire</i>	<i>Health</i>	<i>Reactivity</i>	<i>Other</i>	<i>DOT Class</i>	<i>Waste Codes</i>	<i>Category</i>	<i>Nitrile</i>	<i>4-H/Silver Shield</i>	<i>Neoprene</i>	<i>Latex</i>
Triethylamine	3	2	0	N	3	U404, D001	B	>480		37.2	
Triethylene Diamine							NR		>240		
Triethylene Tetramine					8		B	>480	>240	>480	
Trifluoroacetic Acid					8	D002	Co-Ac		>240		
Trifluoroethanol								7.2		>60	>60
Tripropylamine					3	D001	B	>480		>480	
Tripropylene Glycol Diacrylate									>240		
Turpentine					3	D001	A	30			<5
Valeronitrile										40.8	1.8
Vinyl Acetate	3	2	2	N	3	D001	F1		>480		
Vinyl Chloride	4	2	2	N	2.1	D001, D043	Hood	342	>480		
Vinylcyclohexane						D001	F1	391.8			
Vinylidenefluoride						D001	Hood			<1.2	<1.2
Vinylpyrrolidone							NR		>240		
Xylene	3	2	0	N	3	U239, D001, F003	A	<5	>1440	3	1.2

Key:

DOT Classification	Category	Abbreviation
Explosive 1.1	Mixed CHO Compounds	A
Explosive 1.2	Acid—Heavy Metal	Ac-HMπ
Explosive 1.3	Nitrogenated Hydrocarbons	B
Explosive 1.4	Halogenated Hydrocarbons	C
Explosive 1.5	Corrosive	Co
Explosive 1.6	Corrosive—Acidic	Co-Ac
Flammable Gas 2.1	Corrosive—Basic	Co-Ba
Nonflammable Gas 2.2	Explosive	Ex
Poison Gas/Toxic Gas 2.3	Flammable	F1
Flammable Liquid 3	Keep under Fume Hood	Hood
Flammable Solid 4.1	Keep for Other Uses	Keep
Spontaneously Combustible 4.2	Motor Pool Recycling	MP
Dangerous When Wet 4.3	None	N
Oxidizer 5.1	Non-Regulated	NR
Organic Peroxide 5.2	Organic Peroxide	OP
Poison/Toxic 6.1	Oxidizer	Ox
Infectious Substance 6.2	Poison	P
Radioactive Material 7	Poison—Cyanide	P-Cn
Corrosive Material 8	Poison—Mercury	P-Hg
Misc Hazardous Materials 9	Poison—Heavy Metal	P-HM
	Water Reactive	WR

Source: Adapted from OSHA chemical guidelines and fact sheet, Oklahoma State University 2008. www.pp.okstate.edu/eh/hazamat/PERM.HTM (accessed March 5, 2008)

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