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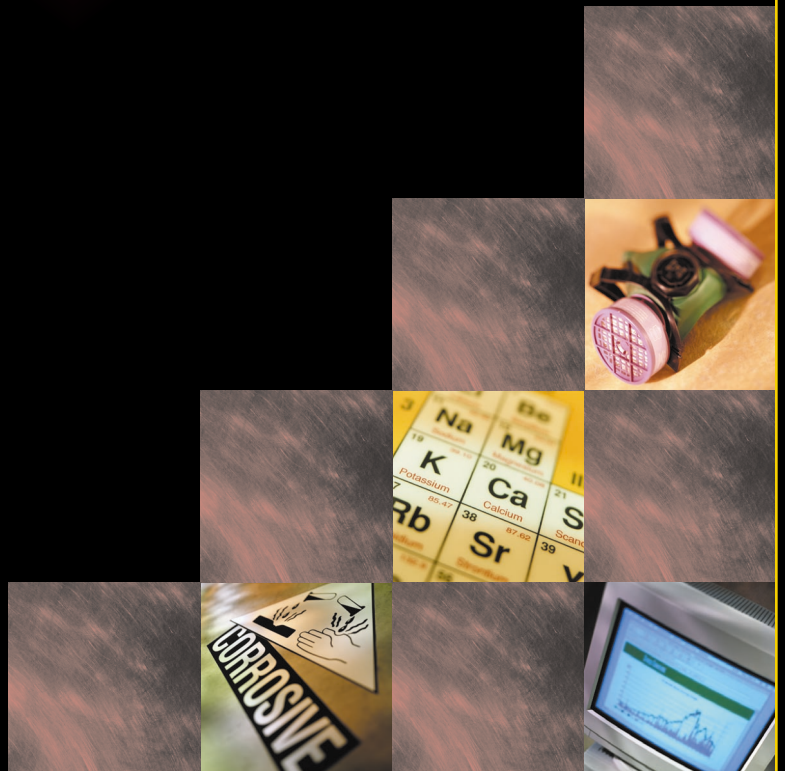
# FUNDAMENTALS OF INDUSTRIAL HYGIENE

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5TH EDITION

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BARBARA A. PLOG  
PATRICIA J. QUINLAN



**FUNDAMENTALS OF  
INDUSTRIAL HYGIENE**  
Fifth Edition

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# **FUNDAMENTALS OF INDUSTRIAL HYGIENE**

**Fifth Edition**

**Barbara A. Plog, MPH, CIH, CSP**  
**Editor in Chief**

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# Foreword

The National Safety Council was chartered on the belief that information and planning are the keys to safety. For those beginning their careers or experienced safety and health professionals, *Fundamentals of Industrial Hygiene* continues to be the acclaimed standard of information for occupational and industrial hygiene professionals.

I encourage all employers, as well as safety and health professionals, to share the Council's commitment to preventing injury and illness and protecting people from hazards in the workplace. Fulfilling this commitment requires accurate, up-to-date information—the kind of comprehensive and current information contained in the fifth edition of the National Safety Council's *Fundamentals of Industrial Hygiene*. Written and edited by prominent industrial hygienists, occupational safety professionals and noted physicians, *Fundamentals of Industrial Hygiene* provides a useful guide to assist the reader, regardless of his or her knowledge base, to recognize, evaluate and control hazards in any type of workplace.

Throughout my own career, I have often referred to the most current edition of *Fundamentals of Industrial Hygiene* for valuable guidance. While at the Occupational Safety and Health Administration, I used earlier editions of *Fundamentals* to obtain in-depth knowledge and insight related to specific occupational environments, processes and procedures. Today, the book remains an indispensable tool to me and to National Safety Council staff, volunteers, members, chapters and affiliates in designing safety and health programs that are grounded in current scientific knowledge and real-life experience.

Whether establishing priorities, collecting and analyzing data, developing procedures to mitigate loss and suffering, or as a simple reference tool, *Fundamentals of Industrial Hygiene* assists every reader in the establishment of safety and health programs that are the foundation of our mission—preventing injury and illness, wherever they may occur.

ALAN C. McMILLAN  
PRESIDENT, NATIONAL SAFETY COUNCIL



# Preface

The fifth edition of *Fundamentals of Industrial Hygiene* comes at a time of continuing congressional activity that seeks to regulate how the federal Occupational Safety and Health Administration (OSHA) promulgates and enforces standards for health and safety in U.S. workplaces.

The words of then-OSHA head Joseph Dear to the American Industrial Hygiene Conference in Kansas City, Missouri, on May 24, 1995, still hold true, that OSHA strives to “guarantee that each worker who leaves for work in the morning arrives home safely each night.” (*The Synergist*, American Industrial Hygiene Association, Volume 6, Number 6–7, p. 10, June/July, 1995.)

It is also clear the fundamental principles of industrial hygiene deserve more emphasis than at any time before.

This edition of *Fundamentals of Industrial Hygiene* presents original new chapters on Particulates (Chapter 8), Dilution Ventilation of Industrial Workplaces (Chapter 20), Respiratory Protection (Chapter 22), The Occupational Medicine Physician (Chapter 25), and The Occupational Health Nurse (Chapter 26). All other chapters have been extensively updated and revised.

The primary purpose of this book is to provide a reference for those who have either an interest in or a direct responsibility for the recognition, evaluation, and control of occupational health hazards. Thus, it is intended to be of use to industrial hygienists, industrial hygiene students, physicians, nurses, safety personnel from labor and industry, labor organizations, public service groups, government agencies, and manufacturers. Others who may find this reference helpful include consultants, architects, lawyers, and allied professional personnel who work with those engaged in business, industry, and agriculture. It is hoped that this book will be of use to those responsible for planning and carrying out programs to minimize occupational health hazards.

An understanding of the fundamentals of industrial hygiene is very important to anyone involved in environmental, community, or occupational health. This manual should be of help in defining the magnitude and extent of an industrial hygiene problem; it should help the reader decide when expert help is needed.

*Fundamentals of Industrial Hygiene* is also intended to be used either as a self-instructional text or as a text for an industrial hygiene fundamentals course, such as the ones offered by the National Safety Council, various colleges and universities, and professional organizations.

The increase in the number and complexity of substances found in the workplace—substances that may spill over into the community environment—makes

imperative the dissemination, as efficiently and conveniently as possible, of certain basic information relating to occupational health hazards and resultant occupational diseases.

The book is organized into seven parts; each can stand alone as a reference source. For that reason, we have permitted a certain amount of redundancy.

*Part One* introduces the subject areas to be covered, in an overview of the fundamentals of industrial hygiene.

*Part Two* includes chapters on the fundamental aspects of the anatomy, physiology, hazards, and pathology of the lungs, skin, ears, and eyes. This background lays the groundwork for understanding how these organ systems interrelate and function.

*Part Three* is concerned with the recognition of specific environmental factors or stresses. The chemical substances, physical agents, and biological and ergonomic hazards present in the workplace are covered. The basic concepts of industrial toxicology are also presented in this section. Anticipation of these hazards is the desired result.

*Part Four* describes methods and techniques of evaluating the hazard. Included is one of the more important aspects of an industrial hygiene program: the methods used to evaluate the extent of exposure to harmful chemical and physical agents. Basic information is given on the various types of instruments available to measure these stresses and on how to use the instruments properly to obtain valid measurements.

*Part Five* deals with the control of the environmental hazards. Although industrial hygiene problems vary, the basic principles of health hazard control, problem-solving techniques, and the examples of engineering control measures given here are general enough to have wide application. To augment the basics, specific information is covered in the chapters on industrial ventilation.

*Part Six* is directed specifically to people responsible for conducting and organizing occupational health and safety programs. The fundamental concepts of the roles of the industrial hygienist, the occupational health nurse, the safety professional, and the occupational medicine physician in implementing a successful program are discussed in detail. Particular attention is paid to a discussion of the practice of industrial hygiene in the public and private sectors and to a description of the professional certification of industrial hygienists.

*Part Seven* contains up-to-date information on government regulations and their impact on the practice of industrial hygiene.

*Appendix A* provides additional resources. One of the most difficult parts of getting any project started is finding sources of help and information. For this reason, we have included a completely updated and comprehensive annotated bibliography and a listing of professional and service organizations, government agencies, and other resources.

Other appendixes include the ACGIH Threshold Limit Values (TLVs<sup>®</sup>) and Biological Exposure Indices (BEIs<sup>®</sup>), a review of mathematics, instructions on conversion of units, and a glossary of terms used in industrial hygiene, occupational health, and pollution control. An extensive index is included to assist the reader in locating information in this text.

We would like to gratefully acknowledge the work of the contributors to previous editions of the *Fundamentals of Industrial Hygiene*.

### First Edition

1—Fundamental Concepts of Industrial Hygiene—Julian B. Olishifski, PE

2—Solvents and Health in the Occupational Environment—Donald R.

McFee, ScD3—Pneumoconiosis-Producing Dusts—Fred Cook, MS

4—Industrial Dermatitis—Charles W. Wyman, BS

5—Industrial Noise—Herbert T. Walworth, MS

- 6—Basic Concepts of Ionizing Radiation Safety—E. L. Alpaugh, PE
- 7—Nonionizing Radiation: Lasers, Microwaves, Light—Julian B. Olishifski, PE
- 8—Effects of Temperature Extremes—E. L. Alpaugh, PE
- 9—Ergonomics Stresses: Physical and Mental—Julian B. Olishifski, PE
- 10—Evaluating the Hazard—J. B. Olishifski, PE
- 11—Toxicology—J. B. Olishifski, PE
- 12—General Methods of Control—J. B. Olishifski, PE
- 13—Respiratory Protective Equipment—A. M. Lundin, BS
- 14—Industrial Ventilation—W. G. Hazard, AM
- 15—General Ventilation and Special Operations—W. G. Hazard, AM
- 20—Setting Up an Industrial Hygiene Program—Julian B. Olishifski, PE
- 21—Sources of Information on Industrial Hygiene—Julian B. Olishifski, PE

**Second Edition**

- 1—Fundamental Concepts—Julian B. Olishifski, PE
- 2—The Lungs—Julian B. Olishifski, PE
- 3—The Skin—Julian B. Olishifski, PE
- 4—The Ear—Julian B. Olishifski, PE
- 5—The Eyes—Julian B. Olishifski, PE
- 6—Solvents—Donald R. McFee, ScD
- 7—Particulates—Edwin L. Alpaugh, PE
- 8—Industrial Dermatoses—Larry L. Hipp
- 9—Industrial Noise—Julian B. Olishifski, PE
- 10—Ionizing Radiation—C. Lyle Cheever, MS, MBA
- 11—Nonionizing Radiation—Edward J. Largent and Julian B. Olishifski, PE
- 12—Temperature Extremes—Edwin L. Alpaugh, PE
- 13—Ergonomics—Bruce A. Hertig
- 14—Biological Hazards—Alvin L. Miller, PhD, CIH and Anne C. Leopold
- 15—Industrial Toxicology—Ralph G. Smith and Julian B. Olishifski, PE
- 16—Evaluation—Edward R. Hermann, CE, PhD, PE, CIH and Jack E. Peterson, PhD, PE, CIH
- 17—Methods of Evaluation—Julian B. Olishifski, PE
- 18—Air-Sampling Instruments—Julian B. Olishifski, PE
- 19—Direct-Reading Gas and Vapor Monitors—Joseph E. Zatek, CSP, CIH, CHCM, CHM
- 20—Methods of Control—Julian B. Olishifski, PE
- 21—Industrial Ventilation—Willis G. Hazard, AM
- 22—General Ventilation—Willis G. Hazard, AM
- 23—Respiratory Protective Equipment—Allen M. Lundin, BS
- 24—Governmental Regulations—M. Chain Robbins, BS, MPH, CSP, PE
- 25—The Industrial Hygienist—Clyde M. Berry
- 26—The Safety Professional—Willis T. McLean
- 27—The Occupational Physician—Carl Zenz, MD, ScD
- 28—The Occupational Health Nurse—Jeanette M. Cornyn
- 29—Industrial Hygiene Program—Edward J. Largent and Julian B. Olishifski, PE
- 30—Sources of Information—Julian B. Olishifski, PE and Robert Pedroza

**Third Edition**

- 1—Overview of Industrial Hygiene—Barbara Plog, MPH, CIH, CSP
- 2—The Lungs—George S. Benjamin, MD, FACS
- 3—The Skin—James S. Taylor, MD
- 4—The Ears—George S. Benjamin, MD, FACS
- 5—The Eyes—George S. Benjamin, MD, FACS
- 6—Solvents—Donald R. McFee, ScD, CIH, PE, CSP; Peter Zavon, CIH
- 7—Particulates—Theodore J. Hogan, PhD, CIH

## PREFACE

- 8—Industrial Dermatoses—James S. Taylor, MD
- 9—Industrial Noise—John J. Standard, MS, MPH, CIH, CSP
- 10—Ionizing Radiation—C. Lyle Cheever, MS, MBA
- 11—Nonionizing Radiation—Larry E. Anderson, PhD
- 12—Temperature Extremes—Theodore J. Hogan, PhD, CIH
- 13—Ergonomics—Karl H. E. Kroemer, PhD
- 14—Biological Hazards—Alvin L. Miller, PhD, CIH; Cynthia S. Volk
- 15—Industrial Toxicology—Carl Zenz, MD, ScD
- 16—Evaluation—Edward R. Hermann, CE, PhD, PE, CIH; Jack E. Peterson, PhD, PE, CIH
- 17—Methods of Evaluation—Julian B. Olishifski, MS, PE, CSP
- 18—Air-Sampling Instruments—Maureen A. Kerwin (now Maureen A. Huey), MPH
- 19—Direct-Reading Gas and Vapor Monitors—Joseph E. Zatek, CSP, CIH, CHCM, CHM
- 20—Methods of Control—Julian B. Olishifski, MS, PE, CSP
- 21—Industrial Ventilation—D. Jeff Burton, PE, CIH
- 22—General Ventilation —D. Jeff Burton, PE, CIH
- 23—Respiratory Protective Equipment—Craig E. Colton, CIH
- 24—The Industrial Hygienist—Barbara A. Plog, MPH, CIH, CSP
- 25—The Safety Professional—Fred A. Manuele, PE, CSP
- 26—The Occupational Physician—Carl Zenz, MD
- 27—The Occupational Health Nurse—Larry Hannigan, RN
- 28—The Industrial Hygiene Program—Maureen A. Kerwin (now Maureen A. Huey), MPH
- 29—Computerizing an Industrial Hygiene Program—Adrienne Whyte, PhD
- 30—Governmental Regulations—M. Chain Robbins, BS, MPH, CSP, PE
- 31—Occupational Safety and Health: The Federal Regulatory Program—A History—Benjamin W. Mintz

### Fourth Edition

- 1—Overview of Industrial Hygiene—Barbara A. Plog, MPH, CIH, CSP
- 2—The Lungs—George S. Benjamin, MD, FACS
- 3—The Skin and Occupational Dermatoses—James S. Taylor, MD
- 4—The Ears—George S. Benjamin, MD, FACS, and Barry J. Benjamin, MD, FACS
- 5—The Eyes—George S. Benjamin, MD, FACS
- 6—Industrial Toxicology—Richard Cohen, MD, MPH, and Kameron Balzer, CIH
- 7—Gases, Vapors, and Solvents—George S. Fulton, MS, CIH
- 8—Particulates—Theodore J. Hogan, PhD, CIH
- 9—Industrial Noise—John Standard, MS, MPH, CIH, CSP
- 10—Ionizing Radiation—C. Lyle Cheever, MS, MBA
- 11—Nonionizing Radiation—Gordon Miller, CIH
- 12—Thermal Stress—Thomas E. Bernard, PhD, CIH
- 13—Ergonomics—Karl H. E. Kroemer, PhD
- 14—Biological Hazards—A. Lynn Harding, MPH, Diane O. Fleming, PhD, and Janet M. Macher, ScD, MPH
- 15—Evaluation—Elizabeth R. Gross, CIH, Elise Pechter, CIH
- 16—Air-Sampling—Maureen A. Huey, MPH, CIH
- 17—Direct-Reading Instruments for Gases, Vapors, and Particulates—Rolfe M.A. Hahne, PhD, CIH
- 18—Methods of Control—Susan M. Raterman, CIH, REPA
- 19—Local Exhaust Ventilation of Industrial Occupancies—D. Jeff Burton, PE, CIH, CSP

- 20—General Ventilation of Industrial Occupancies—D. Jeff Burton, PE, CIH, CSP
- 21—General Ventilation of Nonindustrial Occupancies—D. Jeff Burton, PE, CIH, CSP
- 22—Respiratory Protection—Craig E. Colton, CIH
- 23—The Industrial Hygienist—Jill Niland, MPH, CIH, CSP
- 24—The Safety Professional—Peter B. Rice, CIH, CSP
- 25—The Occupational Physician—Carl Zenz, MD
- 26—Occupational Health Nursing—Barbara J. Burgel, RN, MS, COHN
- 27—The Industrial Hygiene Program—Maureen A. Huey, MPH
- 28—Computerizing an Industrial Hygiene Program—Adrienne A. Whyte, PhD
- 29—Governmental Regulations—Gabriel J. Gillotti, PE
- 30—Occupational Safety and Health: The Federal Regulatory Program—A History—Benjamin W. Mintz
- Appendix A—Deborah Gold, MPH, and Donna Iverson
- Appendix E—European Union Initiatives in Occupational Health and Safety—Robin S. Coyne, CIH, ROH, LIH

We would also like to thank Ron Miller and George Kraficsin, who reviewed material for the fifth edition: special thanks to Patty Quinlan and Jodey Schonfeld, whose excellent work, tireless attention to technical detail, and professionalism, helped to make this edition the best yet.

And finally, this book is dedicated to my family, Michael and Max, who again supported having “the book” in our lives over the past two years; and my mother and father, Doris and Henry Plog; and to the working women and men who are, after all, the point of it all.

Because this manual will be revised periodically, contributions and comments from readers are welcome.

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 DECEMBER 2001

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trator in the San Francisco Regional Office. Currently, as the Director of the Voluntary Programs and Outreach office, he and his staff are responsible for interacting with the public and private sector via speech-making, external training, engaging in partnerships, support Voluntary Protection Programs and other outreach initiatives. Over those 30 years, Mr. Gillotti has made hundreds of presentations and presented papers before local, national, and international groups on the subject of workplace safety and health. Mr. Gillotti is a Registered Professional Engineer in California. He is also the recipient of a Distinguished Career Service award from the Secretary of Labor.

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# **HISTORY AND DEVELOPMENT**

**Part I**





# Overview of Industrial Hygiene

by Barbara A. Plog, MPH, CIH, CSP

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*Industrial hygiene is that science and art devoted to the anticipation, recognition, evaluation, and control of those environmental factors or stresses arising in or from the workplace that may cause sickness, impaired health and well-being, or significant discomfort among workers or among the citizens of the community. Industrial hygienists are occupational health professionals who are concerned primarily with the control of environmental stresses or occupational health hazards that arise as a result of or during the course of work. The industrial hygienist recognizes that environmental stresses may endanger life and health, accelerate the aging process, or cause significant discomfort.*

*The industrial hygienist, although trained in engineering, physics, chemistry, environmental sciences, safety, or biology, has acquired through postgraduate study or experience a knowledge of the health effects of chemical, physical, biological, and ergonomic agents. The industrial hygienist is involved in the monitoring and analysis required to detect the extent of exposure, and the engineering and other methods used for hazard control.*

*Evaluation of the magnitude of work-related environmental hazards and stresses is done by the industrial hygienist, aided by training, experience, and quantitative measurement of the chemical, physical, ergonomic, or biological stresses. The industrial hygienist can thus give an expert opinion as to the degree of risk the environmental stresses pose.*

*Industrial hygiene includes the development of corrective measures in order to control health hazards by either reducing or eliminating the exposure. These control procedures may include the substitution of harmful or toxic materials with less dangerous ones, changing of work processes to eliminate or minimize work exposure, installation of exhaust ventilation systems, good housekeeping (including appropriate waste disposal methods), and the provision of proper personal protective equipment.*

*An effective industrial hygiene program involves the anticipation and recognition of health hazards arising from work operations and processes, evaluation and measurement of the*

*magnitude of the hazard (based on past experience and study), and control of the hazard.*

Occupational health hazards *may mean conditions that cause legally compensable illnesses, or may mean any conditions in the workplace that impair the health of employees enough to make them lose time from work or to cause significant discomfort. Both are undesirable. Both are preventable. Their correction is properly a responsibility of management.*

## PROFESSIONAL ETHICS

In late 1994, the four major U.S. industrial hygiene organizations gave final endorsements to a revised Code of Ethics for the Practice of Industrial Hygiene. These organizations are the American Conference of Governmental Industrial Hygienists (ACGIH), the American Academy of Industrial Hygiene (AAIH), the American Board of Industrial Hygiene (ABIH), and the American Industrial Hygiene Association (AIHA).

The new code defines practice standards (Canons of Ethical Conduct) and applications (interpretive guidelines). The Canons of Ethical Conduct are as follows:

*Industrial Hygienists shall practice their profession following recognized scientific principles with the realization that the lives, health, and well-being of people may depend upon their professional judgment and that they are obligated to protect the health and well-being of people.*

*Industrial Hygienists shall counsel affected parties factually regarding potential health risks and precautions necessary to avoid adverse health effects.*

*Industrial Hygienists shall keep confidential personal and business information obtained during the exercise of industrial hygiene activities, except when required by law or overriding health and safety considerations.*

*Industrial Hygienists shall avoid circumstances where a compromise of professional judgment or conflict of interest may arise.*

*Industrial Hygienists shall perform services only in the areas of their competence.*

*Industrial Hygienists shall act responsibly to uphold the integrity of the profession.*

The interpretive guidelines to the Canons of Ethical Conduct are a series of statements that amplify the code (Figure 1–1).

## The Occupational Health and Safety Team

The chief goal of an occupational health and safety program in a facility is to prevent occupational injury and illness by anticipating, recognizing, evaluating, and controlling occupational health and safety hazards. The medical, industrial hygiene, and safety programs may have distinct, additional program goals but all programs interact and are often considered different components of the overall health and safety program. The occupational health and safety team consists,

then, of the industrial hygienist, the safety professional, the occupational health nurse, the occupational medicine physician, the employees, senior and line management, and others depending on the size and character of the particular facility. All team members must act in concert to provide information and activities, supporting the other parts to achieve the overall goal of a healthy and safe work environment. Therefore, the separate functions must be administratively linked in order to effect a successful and smoothly run program.

The first vital component to an effective health and safety program is the commitment of *senior management* and *line management*. Serious commitment is demonstrated when management is visibly involved in the program both by management support and personal compliance with all health and safety practices. Equally critical is the assignment of the authority, as well as the responsibility, to carry out the health and safety program. The health and safety function must be given the same level of importance and accountability as the production function.

The function of the *industrial hygienist* has been defined above. (Also see Chapter 23, The Industrial Hygienist.) The industrial hygiene program must be made up of several key components: a written program/policy statement, hazard recognition procedures, hazard evaluation and exposure assessment, hazard control, employee training, employee involvement, program evaluation and audit, and record-keeping. (See Chapter 27, The Industrial Hygiene Program, for further discussion.)

The *safety professional* must draw upon specialized knowledge in the physical and social sciences. Knowledge of engineering, physics, chemistry, statistics, mathematics, and principles of measurement and analysis is integrated in the evaluation of safety performance. The safety professional must thoroughly understand the factors contributing to accident occurrence and combine this with knowledge of motivation, behavior, and communication in order to devise methods and procedures to control safety hazards. Because the practice of the safety professional and the industrial hygienist are so closely related, it is rare to find a safety professional who does not practice some traditional industrial hygiene and vice versa. At times, the safety and industrial hygiene responsibilities may be vested in the same individual or position. (See Chapter 24, The Safety Professional.)

The *occupational health nurse* (OHN) is the key to the delivery of comprehensive health care services to workers. Occupational health nursing is focused on the promotion, protection, and restoration of workers' health within the context of a safe and healthy work environment. The OHN provides the critical link between the employee's health status, the work process, and the determination of employee ability to do the job. Knowledge of health and safety regulations, workplace hazards, direct care skills, counseling, teaching, and program management are but a few of the key knowledge areas for the OHN, with strong communication

# Code of Ethics for the Practice of Industrial Hygiene

## Objective

These canons provide standards of ethical conduct for Industrial Hygienists as they practice their profession and exercise their primary mission, to protect the health and well-being of working people and the public from chemical, microbiological, and physical health hazards present at, or emanating from, the workplace.

## Canons of ethical conduct

### CANON 1

Industrial Hygienists shall practice their profession following recognized scientific principles with the realization that the lives, health, and well-being of people may depend upon their professional judgment and that they are obligated to protect the health and well-being of people.

#### INTERPRETIVE GUIDELINES

- Industrial Hygienists should base their professional opinions, judgments, interpretations of findings, and recommendations upon recognized scientific principles and practices which preserve and protect the health and well-being of people.
- Industrial Hygienists shall not distort, alter, or hide facts in rendering professional opinions or recommendations.
- Industrial Hygienists shall not knowingly make statements that misrepresent or omit facts.

### CANON 2

Industrial Hygienists shall counsel affected parties factually regarding potential health risks and precautions necessary to avoid adverse health effects.

#### INTERPRETIVE GUIDELINES

- Industrial Hygienists should obtain information regarding potential health risks from reliable sources.
- Industrial Hygienists should review the pertinent, readily available information to factually inform the affected parties.
- Industrial Hygienists should initiate appropriate measures to see that the health risks are effectively communicated to the affected parties.
- Parties may include management, clients, employees, contractor employees, or others, dependent on circumstances at the time.

### CANON 3

Industrial Hygienists shall keep confidential personal and business information obtained during the exercise of industrial hygiene activities, except when required by law or overriding health and safety considerations.

#### INTERPRETIVE GUIDELINES

- Industrial Hygienists should report and communicate information which is necessary to protect the health and safety of workers and the community.
- If their professional judgment is overruled under circumstances where the health and lives of people are endangered, Industrial Hygienists shall notify their employer, client, or other such authority, as may be appropriate.
- Industrial Hygienists should release confidential personal or business information only with the information owners express authorization, except when there is a duty to disclose information as required by law or regulation.

### CANON 4

Industrial Hygienists shall avoid circumstances where a compromise of professional judgment or conflict of interest may arise.

#### INTERPRETIVE GUIDELINES

- Industrial Hygienists should promptly disclose known or potential conflicts of interest to parties that may be affected.
- Industrial Hygienists shall not solicit or accept financial or other valuable consideration from any party, directly or indirectly, which is intended to influence professional judgment.
- Industrial Hygienists shall not offer any substantial gift, or other valuable consideration, in order to secure work.
- Industrial Hygienists should advise their clients or employer when they initially believe a project to improve industrial hygiene conditions will not be successful.
- Industrial Hygienists should not accept work that negatively impacts the ability to fulfill existing commitments.
- In the event that this Code of Ethics appears to conflict with another professional code to which Industrial Hygienists are bound, they will resolve the conflict in the manner that protects the health of affected parties.

### CANON 5

Industrial Hygienists shall perform services only in the areas of their competence.

#### INTERPRETIVE GUIDELINES

- Industrial Hygienists should undertake to perform services only when qualified by education, training, or experience in the specific technical fields involved, unless sufficient assistance is provided by qualified associates, consultants, or employees.
- Industrial Hygienists shall obtain appropriate certifications, registrations, and/or licenses as required by federal, state, and/or local regulatory agencies prior to providing industrial hygiene services, where such credentials are required.
- Industrial Hygienists shall affix or authorize the use of their seal, stamp, or signature only when the document is prepared by the Industrial Hygienist or someone under their direction and control.

### CANON 6

Industrial Hygienists shall act responsibly to uphold the integrity of the profession.

#### INTERPRETIVE GUIDELINES

- Industrial Hygienists shall avoid conduct or practice which is likely to discredit the profession or deceive the public.
- Industrial Hygienists shall not permit use of their name or firm name by any person or firm which they have reason to believe is engaging in fraudulent or dishonest industrial hygiene practices.
- Industrial Hygienists shall not use statements in advertising their expertise or services containing a material misrepresentation of fact or omitting a material fact necessary to keep statements from being misleading.
- Industrial Hygienists shall not knowingly permit their employees, employers, or others to misrepresent the individuals' professional background, expertise, or services which are misrepresentations of fact.
- Industrial Hygienists shall not misrepresent their professional education, experience, or credentials.

**Figure 1–1.** The joint Code of Ethics for the Practice of Industrial Hygiene endorsed by the AIHA, the ABIH, the AAIH, and the ACGIH. (From *ACGIH Today!* 3(1), January 1995.) These guidelines may be supplemented when necessary, as ethical issues and claims arise.

skills of the utmost importance. OHNs deliver high-quality care at worksites and support the primary prevention dictum that most workplace injuries and illnesses are preventable. If injuries occur, OHNs use a case-management approach to return injured employees to appropriate work on a timely basis. The OHN often functions in multiple roles within one job position, including clinician, educator, manager, and consultant. (See Chapter 26, The Occupational Health Nurse.)

The *occupational medicine physician* has acquired, through graduate training or experience, extensive knowledge of cause and effect relationships of chemical, physical, biological, and ergonomic hazards, the signs and symptoms of chronic and acute exposures, and the treatment of adverse effects. The primary goal of the occupational medicine physician is to prevent occupational illness and, when illness occurs, to restore employee health within the context of a healthy and safe workplace. Many regulations provide for a minimum medical surveillance program and specify mandatory certain tests and procedures.

The occupational medicine physician and the occupational health nurse should be familiar with all jobs, materials, and processes used. An occasional workplace inspection by the medical team enables them to suggest protective measures and aids them in recommending placement of employees in jobs best suited to their physical capabilities. (See discussion of the Americans with Disabilities Act in Chapter 26, The Occupational Health Nurse.)

Determining the work-relatedness of disease is another task for the occupational medicine physician. The industrial hygienist provides information about the manufacturing operations and work environment of a company to the medical department as well. In many cases it is extremely difficult to differentiate between the symptoms of occupational and nonoccupational disease. The industrial hygienist supplies information on the work operations and their associated hazards and enables the medical department to correlate the employee's condition and symptoms with potential workplace health hazards.

The *employee* plays a major role in the occupational health and safety program. Employees are excellent sources of information on work processes and procedures and the hazards of their daily operations. Industrial hygienists benefit from this source of information and often obtain innovative suggestions for controlling hazards.

The *safety and health committee* provides a forum for securing the cooperation, coordination, and exchange of ideas among those involved in the health and safety program. It provides a means of involving employees in the program. The typical functions of the safety and health committee include, among others, to examine company safety and health issues and recommend policies to management, conduct periodic workplace inspections, and evaluate and promote interest in the health and safety program. Joint labor-management safety and health committees are

often used where employees are represented by a union. The committee meetings also present an opportunity to discuss key industrial hygiene program concerns and to formulate appropriate policies.

## FEDERAL REGULATIONS

Before 1970, government regulation of health and safety matters was largely the concern of state agencies. There was little uniformity in codes and standards or in the application of these standards. Almost no enforcement procedures existed.

On December 29, 1970, the Occupational Safety and Health Act, known as the OSHAct, was enacted by Congress. Its purpose was to "assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources." The OSHAct sets out two duties for employers:

- > Each employer shall furnish to each employee a place of employment, which is free from recognized hazards that are causing or are likely to cause death or serious harm to their employees.
- > Each employer shall comply with occupational safety and health standards under the Act.

For employees, the OSHAct states that "Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to the Act which are applicable to his own actions and conduct."

The Occupational Safety and Health Administration (OSHA) came into official existence on April 28, 1971, the date the OSHAct became effective. It is housed within the U.S. Department of Labor. The OSHAct also established the National Institute for Occupational Safety and Health (NIOSH), which is housed within the Centers for Disease Control and Prevention (CDC). The CDC is part of the U.S. Public Health Service.

OSHA was empowered to promulgate safety and health standards with technical advice from NIOSH. OSHA is empowered to enter workplaces to investigate alleged violations of these standards and to perform routine inspections. Formal complaints of standards violations may be made by employees or their representatives. The OSHAct also gives OSHA the right to issue citations and penalties, provide for employee walkarounds or interview of employees during the inspection, require employers to maintain accurate records of exposures to potentially hazardous materials, and to inform employees of the monitoring results. OSHA is also empowered to provide up to 50/50 funding with states that wish to establish state OSHA programs that are at least as effective as the federal program. As of this date, there are 23 approved state plans and approved plans from Puerto Rico and the Virgin Islands.

NIOSH is the principal federal agency engaged in occupational health and safety research. The agency is responsible for identifying hazards and making recommendations for

regulations. These recommendations are called Recommended Exposure Limits (RELs). NIOSH also issues criteria documents and health hazard alerts on various hazards and is responsible for testing and certifying respiratory protective equipment.

Part of NIOSH research takes place during activities called *Health Hazard Evaluations*. These are on-the-job investigations of reported worker exposures that are carried out in response to a request by either the employer or the employee or employee representative. In addition to its own research program, NIOSH also funds supportive research activities at a number of universities, colleges, and private facilities.

NIOSH has training grant programs in colleges and universities across the nation. These are located at designated Education and Research Centers (ERCs). ERCs train occupational medicine physicians, occupational health nurses, industrial hygienists, safety professionals, ergonomists, and others in the safety and health field. They also provide continuing professional education for practicing occupational health and safety professionals. (See Chapter 28, Government Regulations, and Chapter 29, History of the Federal Occupational Safety and Health Administration, for a full discussion of federal agencies and regulations.)

## ENVIRONMENTAL FACTORS OR STRESSES

The various environmental factors or stresses that can cause sickness, impaired health, or significant discomfort in workers can be classified as chemical, physical, biological, or ergonomic.

**Chemical hazards.** These arise from excessive airborne concentrations of mists, vapors, gases, or solids in the form of dusts or fumes. In addition to the hazard of inhalation, some of these materials may act as skin irritants or may be toxic by absorption through the skin.

**Physical hazards.** These include excessive levels of nonionizing radiation (see Chapter 10), ionizing radiation (see Chapter 11), noise (see Chapter 9), vibration, and extremes of temperature (see Chapter 12) and pressure.

**Ergonomic hazards.** These include improperly designed tools, work areas, or work procedures. Improper lifting or reaching, poor visual conditions, or repeated motions in an awkward position can result in accidents or illnesses in the occupational environment. Designing the tools and the job to fit the worker is of prime importance. Engineering and biomechanical principles must be applied to eliminate hazards of this kind (see Chapter 13).

**Biological hazards.** These are any living organism or its properties that can cause an adverse response in humans. They can be part of the total environment or associated with

a particular occupation. Work-related illnesses due to biological agents have been widely reported, but in many workplaces their presence and resultant illness are not well recognized. It is estimated that the population at risk for occupational biohazards may be several hundred million workers worldwide (see Chapter 14).

Exposure to many of the harmful stresses or hazards listed can produce an immediate response due to the intensity of the hazard, or the response can result from longer exposure at a lower intensity.

In certain occupations, depending on the duration and severity of exposure, the work environment can produce significant subjective responses or strain. The energies and agents responsible for these effects are called environmental stresses. An employee is most often exposed to an intricate interplay of many stresses, not to a single environmental stress.

## Chemical Hazards

The majority of occupational health hazards arise from inhaling chemical agents in the form of vapors, gases, dusts, fumes, and mists, or by skin contact with these materials. The degree of risk of handling a given substance depends on the magnitude and duration of exposure. (See Chapter 15, Evaluation, for more details.)

To recognize occupational factors or stresses, a health and safety professional must first know about the chemicals used as raw materials and the nature of the products and by-products manufactured. This sometimes requires great effort. The required information can be obtained from the Material Safety Data Sheet (MSDS) (Figure 1–2) that must be supplied by the chemical manufacturer or importer for all hazardous materials under the OSHA hazard communication standard. The MSDS is a summary of the important health, safety, and toxicological information on the chemical or the mixture ingredients. Other stipulations of the hazard communication standard require that all containers of hazardous substances in the workplace be labeled with appropriate warning and identification labels. See Chapter 28, Government Regulations, and Chapter 29, History of the Federal Occupational Safety and Health Administration, for further discussion of the hazard communication standard.

If the MSDS or the label does not give complete information but only trade names, it may be necessary to contact the manufacturer to obtain this information.

Many industrial materials such as resins and polymers are relatively inert and nontoxic under normal conditions of use, but when heated or machined, they may decompose to form highly toxic by-products. Information about these hazardous products and by-products must also be included in the company's hazard communication program.

Breathing of some materials can irritate the upper respiratory tract or the terminal passages of the lungs and the air sacs, depending upon the solubility of the material. Contact of irritants with the skin surface can produce various kinds of dermatitis.

The presence of excessive amounts of biologically inert gases can dilute the atmospheric oxygen below the level required to maintain the normal blood saturation value for oxygen and disturb cellular processes. Other gases and vapors can prevent the blood from carrying oxygen to the tissues or interfere with its transfer from the blood to the tissue, thus producing chemical asphyxia or suffocation. Carbon monoxide and hydrogen cyanide are examples of chemical asphyxiants.

Some substances may affect the central nervous system and brain to produce narcosis or anesthesia. In varying degrees, many solvents have these effects. Substances are often classified, according to the major reaction they produce, as asphyxiants, systemic toxins, pneumoconiosis-producing agents, carcinogens, irritant gases, and so on.

### SOLVENTS

This section discusses some general hazards arising from the use of solvents; a more detailed description is given in Chapter 7, Gases, Vapors, and Solvents.

Solvent vapors enter the body mainly by inhalation, although some skin absorption can occur. The vapors are absorbed from the lungs into the blood and are distributed mainly to tissues with a high content of fat and lipids, such as the central nervous system, liver, and bone marrow. Solvents include aliphatic and aromatic hydrocarbons, alcohols, aldehydes, ketones, chlorinated hydrocarbons, and carbon disulfide.

Occupational exposure can occur in many different processes, such as the degreasing of metals in the machine industry and the extraction of fats or oils in the chemical or food industry, dry cleaning, painting, and the plastics industry.

The widespread industrial use of solvents presents a major problem to the industrial hygienist, the safety professional, and others responsible for maintaining a safe, healthful working environment. Getting the job done using solvents without hazard to employees or property depends on the proper selection, application, handling, and control of solvents and an understanding of their properties.

A working knowledge of the physical properties, nomenclature, and effects of exposure is absolutely necessary in making a proper assessment of a solvent exposure. Nomenclature can be misleading. For example, benzine is sometimes mistakenly called benzene, a completely different solvent. Some commercial grades of benzine may contain benzene as a contaminant.

Use the information on the MSDS (Figure 1–2) or the manufacturer's label for the specific name and composition of the solvents involved.

The severity of a hazard in the use of organic solvents and other chemicals depends on the following factors:

- > How the chemical is used
- > Type of job operation, which determines how the workers are exposed
- > Work pattern
- > Duration of exposure

- > Operating temperature
- > Exposed liquid surface
- > Ventilation rates
- > Evaporation rate of solvent
- > Pattern of airflow
- > Concentration of vapor in workroom air
- > Housekeeping

The hazard is determined not only by the toxicity of the solvent or chemical itself but by the conditions of its use (who, what, how, where, and how long).

The health and safety professional can obtain much valuable information by observing the manner in which health hazards are generated, the number of people involved, and the control measures in use.

After the list of chemicals and physical conditions to which employees are exposed has been prepared, determine which of the chemicals or agents may result in hazardous exposures and need further study.

Dangerous materials are chemicals that may, under specific circumstances, cause injury to persons or damage to property because of reactivity, instability, spontaneous decomposition, flammability, or volatility. Under this definition, we will consider substances, mixtures, or compounds that are explosive, corrosive, flammable, or toxic.

Explosives are substances, mixtures, or compounds capable of entering into a combustion reaction so rapidly and violently as to cause an explosion.

Corrosives are capable of destroying living tissue and have a destructive effect on other substances, particularly on combustible materials; this effect can result in a fire or explosion.

Flammable liquids are liquids with a flash point of 100 F (38 C) or less, although those with higher flash points can be both combustible and dangerous.

Toxic chemicals are gases, liquids, or solids that, through their chemical properties, can produce injurious or lethal effects on contact with body cells.

Oxidizing materials are chemicals that decompose readily under certain conditions to yield oxygen. They may cause a fire in contact with combustible materials, can react violently with water, and when involved in a fire can react violently.

Dangerous gases are those that can cause lethal or injurious effects and damage to property by their toxic, corrosive, flammable, or explosive physical and chemical properties.

Storage of dangerous chemicals should be limited to one day's supply, consistent with the safe and efficient operation of the process. The storage should comply with applicable local laws and ordinances. An approved storehouse should be provided for the main supply of hazardous materials.

For hazardous materials, MSDSs can be consulted for toxicological information. The information is useful to the medical, purchasing, managerial, engineering, and health and safety departments in setting guidelines for safe use of these materials. This information is also very helpful in an emergency. The information should cover materials actually

<p><b>Material Safety Data Sheet</b>                  May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.</p>		<p><b>U.S. Department of Labor</b>                  Occupational Safety and Health Administration                  (Non-Mandatory Form)                  Form Approved                  OMB No. 1218-0072</p>		
<p><b>IDENTITY</b> (As Used on Label and List)</p>		<p><i>Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.</i></p>		
<p><b>Section I</b></p>				
<p>Manufacturer's Name</p>		<p>Emergency Telephone Number</p>		
<p>Address (Number, Street, City, State, and ZIP Code)</p>		<p>Telephone Number for Information</p>		
<p></p>		<p>Date Prepared</p>		
<p></p>		<p>Signature of Preparer (optional)</p>		
<p><b>Section II — Hazardous Ingredients/Identity Information</b></p>				
<p>Hazardous Components (Specific Chemical Identity, Common Name(s))</p>	<p>OSHA PEL</p>	<p>ACGIH TLV</p>	<p>Other Limits Recommended</p>	<p>% (optional)</p>

<b>Section V — Reactivity Data</b>			
Stability	Unstable		Conditions to Avoid
	Stable		
Incompatibility ( <i>Materials to Avoid</i> )			
Hazardous Decomposition or Byproducts			
Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur		
<b>Section VI — Health Hazard Data</b>			
Route(s) of Entry:	Inhalation?	Skin?	Ingestion?
Health Hazards ( <i>Acute and Chronic</i> )			
Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulated?
Signs and Symptoms of Exposure			
Medical Conditions Generally Aggravated by Exposure			
Emergency and First Aid Procedures			
<b>Section VII — Precautions for Safe Handling and Use</b>			
Steps to Be Taken in Case Material Is Released or Spilled			
Waste Disposal Method			
Precautions to Be Taken in Handling and Storing			
Other Precautions			
<b>Section VIII — Control Measures</b>			
Respiratory Protection ( <i>Specify Type</i> )			
Ventilation	Local Exhaust	Special	
	Mechanical ( <i>General</i> )	Other	
Protective Gloves	Eye Protection		
Other Protective Clothing or Equipment			
Work/Hygienic Practices			

Figure 1-2. (Continued)

in use and those that may be contemplated for early future use. Possibly the best and earliest source of information concerning such materials is the purchasing agent. Thus, a close liaison should be set up between the purchasing agent and health and safety personnel so that early information is available concerning materials in use and those to be ordered, and to ensure that MSDSs are received and reviewed for all hazardous substances.

### TOXICITY VERSUS HAZARD

The toxicity of a material is not synonymous with its hazard. *Toxicity* is the capacity of a material to produce injury or harm when the chemical has reached a sufficient concentration at a certain site in the body. *Hazard* is the probability that this concentration in the body will occur. This degree of hazard is determined by many factors or elements. (See Chapter 6, Industrial Toxicology.)

The key elements to be considered when evaluating a health hazard are as follows:

- What is the route of entry of the chemical into the body?
- How much of the material must be in contact with a body cell and for how long to produce injury?
- What is the probability that the material will be absorbed or come in contact with body cells?
- What is the rate of generation of airborne contaminants?
- What control measures are in place?

The effects of exposure to a substance depend on dose, rate, physical state of the substance, temperature, site of absorption, diet, and general state of a person's health.

### Physical Hazards

Problems caused by such things as noise, temperature extremes, ionizing radiation, nonionizing radiation, and pressure extremes are physical stresses. It is important that the employer, supervisor, and those responsible for safety and health be alert to these hazards because of the possible immediate or cumulative effects on the health of employees.

### NOISE

Noise (unwanted sound) is a form of vibration conducted through solids, liquids, or gases. The effects of noise on humans include the following:

- Psychological effects (noise can startle, annoy, and disrupt concentration, sleep, or relaxation)
- Interference with speech communication and, as a consequence, interference with job performance and safety
- Physiological effects (noise-induced hearing loss, or aural pain when the exposure is severe)

**Damage risk criteria.** If the ear is subjected to high levels of noise for a sufficient period of time, some loss of hearing may occur. A number of factors can influence the effect of the noise exposure:

- Variation in individual susceptibility
- Total energy of the sound

- Frequency distribution of the sound
- Other characteristics of the noise exposure, such as whether it is continuous, intermittent, or made up of a series of impacts
- Total daily duration of exposure
- Length of employment in the noise environment

Because of the complex relationships of noise and exposure time to threshold shift (reduction in hearing level) and the many contributory causes, establishing criteria for protecting workers against hearing loss is difficult. However, criteria have been developed to protect against hearing loss in the speech-frequency range. These criteria are known as the Threshold Limit Values for Noise. (See Chapter 9, Industrial Noise, and Appendix B, The ACGIH Threshold Limit Values and Biological Exposure Indices, for more details.)

There are three nontechnical guidelines to determine whether the work area has excessive noise levels:

- If it is necessary to speak very loudly or shout directly into the ear of a person in order to be understood, it is possible that the exposure limit for noise is being exceeded. Conversation becomes difficult when the noise level exceeds 70 decibels (dBA).
- If employees say that they have heard ringing noises in their ears at the end of the workday, they may be exposed to too much noise.
- If employees complain that the sounds of speech or music seem muffled after leaving work, but that their hearing is fairly clear in the morning when they return to work, they may be exposed to noise levels that cause a partial temporary loss of hearing, which can become permanent with repeated exposure.

**Permissible levels.** The criteria for hearing conservation, required by OSHA in 29 *CFR* 1910.95, establishes the permissible levels of harmful noise to which an employee may be subjected. The permissible decibel levels and hours (duration per day) are specified. For example, a noise level of 90 dBA is permissible for eight hours, 95 dBA for four hours, etc. (See Chapter 9, Industrial Noise, for more details.)

The regulations stipulate that when employees are subjected to sound that exceeds the permissible limits, feasible administrative or engineering controls shall be used. If such controls fail to reduce sound exposure within permissible levels, personal protective equipment must be provided and used to reduce sound levels to within permissible levels.

According to the Hearing Conservation Amendment to 29 *CFR* 1910.95, in all cases when the sound levels exceed 85 dBA on an eight-hour time-weighted average (TWA), a continuing, effective hearing conservation program shall be administered. The Hearing Conservation Amendment specifies the essential elements of a hearing conservation program. (See Chapter 9, Industrial Noise, for a discussion of noise and OSHA noise regulations.)

Administering a hearing conservation program goes beyond the wearing of earplugs or earmuffs. Such programs

can be complex, and professional guidance is essential for establishing programs that are responsive to the need. Valid noise exposure information correlated with audiometric tests results is needed to help health and safety and medical personnel to make informed decisions about hearing conservation programs.

The effectiveness of a hearing conservation program depends on the cooperation of employers, employees, and others concerned. Management's responsibility in such a program includes noise measurements, initiation of noise control measures, provision of hearing protection equipment, audiometric testing of employees to measure their hearing levels (thresholds), and information and training programs for employees.

The employee's responsibility is to properly use the protective equipment provided by management, and to observe any rules or regulations on the use of equipment in order to minimize noise exposure.

### EXTREMES OF TEMPERATURE

Probably the most elementary factor of environmental control is control of the thermal environment in which people work. Extremes of temperature, or thermal stress, affect the amount of work people can do and the manner in which they do it. In industry, the problem is more often high temperatures rather than low temperatures. (More details on this subject are given in Chapter 12, Thermal Stress.)

The body continuously produces heat through its metabolic processes. Because the body processes are designed to operate only within a very narrow range of temperature, the body must dissipate this heat as rapidly as it is produced if it is to function efficiently. A sensitive and rapidly acting set of temperature-sensing devices in the body must also control the rates of its temperature-regulating processes. (This mechanism is described in Chapter 3, The Skin and Occupational Dermatoses.)

Heat stress is a common problem, as are the problems presented by a very cold environment. Evaluation of heat stress in a work environment is not simple. Considerably more is involved than simply taking a number of air-temperature measurements and making decisions on the basis of this information.

One question that must be asked is whether the temperature is merely causing discomfort or whether continued exposure will cause the body temperature to fall below or rise above safe limits. It is difficult for a person with only a clipboard full of data to interpret how another person actually feels or is adversely affected.

People function efficiently only in a very narrow body temperature range, a core temperature measured deep inside the body, not on the skin or at body extremities. Fluctuations in core temperatures exceeding 2 F below or 3 F above the normal core temperature of 99.6 F (37.6 C), which is 98.6 F (37 C) mouth temperature, impair performance markedly. If this five-degree range is exceeded, a health hazard exists.

The body attempts to counteract the effects of high temperature by increasing the heart rate. The capillaries in the skin also dilate to bring more blood to the surface so that the rate of cooling is increased. Sweating is an important factor in cooling the body.

Heatstroke is caused by exposure to an environment in which the body is unable to cool itself sufficiently. Heatstroke is a much more serious condition than heat cramps or heat exhaustion. An important predisposing factor is excessive physical exertion or moderate exertion in extreme heat conditions. The method of control is to reduce the temperature of the surroundings or to increase the ability of the body to cool itself, so that body temperature does not rise. In heatstroke, sweating may cease and the body temperature can quickly rise to fatal levels. It is critical to undertake emergency cooling of the body even while medical help is on the way. Studies show that the higher the body temperature on admission to emergency rooms, the higher the fatality rate. Heatstroke is a life-threatening medical emergency.

Heat cramps can result from exposure to high temperature for a relatively long time, particularly if accompanied by heavy exertion, with excessive loss of salt and moisture from the body. Even if the moisture is replaced by drinking plenty of water, an excessive loss of salt can cause heat cramps or heat exhaustion.

Heat exhaustion can also result from physical exertion in a hot environment. Its signs are a mildly elevated temperature, pallor, weak pulse, dizziness, profuse sweating, and cool, moist skin.

### ENVIRONMENTAL MEASUREMENTS

In many heat stress studies, the variables commonly measured are work energy metabolism (often estimated rather than measured), air movement, air temperature, humidity, and radiant heat. See Chapter 12, Thermal Stress, for illustrations and more details.

Air movement is measured with some type of anemometer and the air temperature with a thermometer, often called a *dry bulb thermometer*.

Humidity, or the moisture content of the air, is generally measured with a psychrometer, which gives both dry bulb and wet bulb temperatures. Using these temperatures and referring to a psychrometric chart, the relative humidity can be established.

The term *wet bulb* is commonly used to describe the temperature obtained by having a wet wick over the mercury-well bulb of an ordinary thermometer. Evaporation of moisture in the wick, to the extent that the moisture content of the surrounding air permits, cools the thermometer to a temperature below that registered by the dry bulb. The combined readings of the dry bulb and wet bulb thermometers are then used to calculate percent relative humidity, absolute moisture content of the air, and water vapor pressure.

Radiant heat is a form of electromagnetic energy similar to light but of longer wavelength. Radiant heat (from such

sources as red-hot metal, open flames, and the sun) has no appreciable heating effect on the air it passes through, but its energy is absorbed by any object it strikes, thus heating the person, wall, machine, or whatever object it falls on. Protection requires placing opaque shields or screens between the person and the radiating surface.

An ordinary dry bulb thermometer alone will not measure radiant heat. However, if the thermometer bulb is fixed in the center of a metal toilet float that has been painted dull black, and the top of the thermometer stem protrudes outside through a one-hole cork or rubber stopper, radiant heat can be measured by the heat absorbed in this sphere. This device is known as a globe thermometer.

**Heat loss.** Conduction is an important means of heat loss when the body is in contact with a good cooling agent, such as water. For this reason, when people are immersed in cold water, they become chilled much more rapidly and effectively than when exposed to air of the same temperature.

Air movement cools the body by convection: The moving air removes the air film or the saturated air (which is formed very rapidly by evaporation of sweat) and replaces it with a fresh air layer capable of accepting more moisture from the skin.

**Heat stress indices.** The methods commonly used to estimate heat stress relate various physiological and environmental variables and end up with one number that then serves as a guide for evaluating stress. For example, the effective temperature index combines air temperature (dry bulb), humidity (wet bulb), and air movement to produce a single index called an effective temperature.

Another index is the wet bulb globe temperature (WBGT). The numerical value of the WBGT index is calculated by the following equations.

Indoors or outdoors with no solar loads:

$$\text{WBGT}_{\text{in}} = 0.7 T_{\text{nw}} + 0.3 T_{\text{gt}}$$

Outdoors with solar load:

$$\text{WBGT}_{\text{out}} = 0.7 T_{\text{nw}} + 0.2 T_{\text{gt}} + 0.1 T_{\text{db}}$$

where

$T_{\text{nw}}$  = natural wet bulb temperature

$T_{\text{gt}}$  = globe temperature

$T_{\text{db}}$  = dry bulb temperature

In its *Criteria Document on Hot Environments* (see Bibliography), NIOSH states that when impermeable clothing is worn, the WBGT should not be used because evaporative cooling would be limited. The WBGT combines the effects of humidity and air movement, air temperature and radiation, and air temperature. It has been successfully used for environmental heat stress monitoring at military camps to control heat stress casualties. The measurements are few and easy to make; the instrumentation is simple, inexpensive, and rugged; and the calculations are straightforward. It is

also the index used in the *ACGIH Threshold Limit Values (TLVs<sup>®</sup>) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs<sup>®</sup>)* book (see Appendix B). The ACGIH recommends TLVs for continuous work in hot environments as well as when 25, 50, or 75 percent of each working hour is at rest. Regulating allowable exposure time in the heat is a viable technique for permitting necessary work to continue under heat-stress conditions that would be intolerable for continuous exposure. The NIOSH criteria document also contains a complete recommended heat stress control program including work practices.

Work practices include acclimation periods, work and rest regimens, distribution of work load with time, regular breaks of a minimum of one per hour, provision for water intake, protective clothing, and application of engineering controls. Experience has shown that workers do not stand a hot job very well at first, but develop tolerance rapidly through acclimation and acquire full endurance in a week to a month. (For more details, see Chapter 12, Thermal Stress, and the NIOSH criteria document.)

## COLD STRESS

Generally, the answer to a cold work area is to supply heat where possible, except for areas that must be cold, such as food storage areas.

General hypothermia is an acute problem resulting from prolonged cold exposure and heat loss. If an individual becomes fatigued during physical activity, he or she will be more prone to heat loss, and as exhaustion approaches, sudden vasodilation (blood vessel dilation) occurs with resultant rapid loss of heat.

Cold stress is proportional to the total thermal gradient between the skin and the environment because this gradient determines the rate of heat loss from the body by radiation and convection. When vasoconstriction (blood vessel constriction) is no longer adequate to maintain body heat balance, shivering becomes an important mechanism for increasing body temperature by causing metabolic heat production to increase to several times the resting rate.

General physical activity increases metabolic heat. With clothing providing the proper insulation to minimize heat loss, a satisfactory microclimate can be maintained. Only exposed body surfaces are likely to be excessively chilled and frostbitten. If clothing becomes wet either from contact with water or due to sweating during intensive physical work, its cold-insulating property is greatly diminished.

Frostbite occurs when the skin tissues freeze. Theoretically, the freezing point of the skin is about 30 F (1 C); however, with increasing wind velocity, heat loss is greater and frostbite occurs more rapidly. Once started, freezing progresses rapidly. For example, if the wind velocity reaches 20 mph, exposed flesh can freeze within about 1 minute at 14 F (10 C). Furthermore, if the skin comes in direct contact with objects whose surface temperature is below the freezing point, frostbite can develop at the point of contact despite

warm environmental temperatures. Air movement is more important in cold environments than in hot because the combined effect of wind and temperature can produce a condition called *windchill*. The windchill index should be consulted by everyone facing exposure to low temperature and strong winds. (See Chapter 12, Thermal Stress.)

### IONIZING RADIATION

A brief description of ionizing radiation hazards is given in this section; for a complete description, see Chapter 10, Ionizing Radiation.

To understand a little about ionization, recall that the human body is made up of various chemical compounds that are in turn composed of molecules and atoms. Each atom has a nucleus with its own outer system of electrons.

When ionization of body tissues occurs, some of the electrons surrounding the atoms are forcibly ejected from their orbits. The greater the intensity of the ionizing radiation, the more ions are created and the more physical damage is done to the cells.

Light consisting of electromagnetic radiation from the sun that strikes the surface of the earth is very similar to x-rays and gamma-radiation; it differs only in wavelength and energy content. (See description in Chapter 11, Non-ionizing Radiation.) However, the energy level of sunlight at the earth's surface is too low to disturb orbital electrons, so sunlight is not considered ionizing even though it has enough energy to cause severe skin burns over a period of time.

The exact mechanism of the manner in which ionization affects body cells and tissue is complex. At the risk of oversimplifying some basic physical principles and ignoring others, the purpose of this section is to present enough information so the health and safety professional will recognize the problems involved and know when to call on health physicists or radiation safety experts for help.

At least three basic factors must be considered in such an approach to radiation safety:

- Radioactive materials emit energy that can damage living tissue.
- Different kinds of radioactivity present different kinds of radiation safety problems. The types of ionizing radiation we will consider are alpha-, beta-, x-ray, and gamma-radiation, and neutrons.
- Radioactive materials can be hazardous in two different ways. Certain materials can be hazardous even when located some distance away from the body; these are external hazards. Other types are hazardous only when they get inside the body through breathing, eating, or broken skin. These are called internal radiation hazards.

Instruments are available for evaluating possible radiation hazards. Meters or other devices are used for measuring radiation levels and doses.

**Kinds of radioactivity.** The five kinds of radioactivity that are of concern are alpha, beta, x-ray, gamma, and neutron.

The first four are the most important because neutron sources usually are not used in ordinary manufacturing operations.

Of the five types of radiation mentioned, alpha-particles are the least penetrating. They do not penetrate thin barriers. For example, paper, cellophane, and skin stop alpha-particles.

Beta-radiation has considerably more penetrating power than alpha radiation. A quarter of an inch of aluminum can stop the more energetic betas. Virtually everyone is familiar with the penetrating ability of x rays and the fact that a barrier such as concrete or lead is required to stop them.

Gamma-rays are, for all practical purposes, the same as x rays and require the same kinds of heavy shielding materials.

Neutrons are very penetrating and have characteristics that make it necessary to use shielding materials of high hydrogen atom content rather than high mass alone.

Although the type of radiation from one radioactive material may be the same as that emitted by several other different radioactive materials, there may be a wide variation in energies.

The amount of energy a particular kind of radioactive material possesses is defined in terms of MeV (million electron volts); the greater the number of MeV, the greater the energy. Each radioactive material emits its own particular kinds of radiation, with energy measured in terms of MeV.

**External versus internal hazards.** Radioactive materials that emit x-rays, gamma-rays, or neutrons are external hazards. In other words, such materials can be located some distance from the body and emit radiation that produces ionization (and thus damage) as it passes through the body. Control by limiting exposure time, working at a safe distance, use of barriers or shielding, or a combination of all three is required for adequate protection against external radiation hazards.

As long as a radioactive material that emits only alpha-particles remains outside the body, it will not cause trouble. Internally, it is a hazard because the ionizing ability of alpha particles at very short distances in soft tissue makes them a veritable bulldozer. Once inside the body—in the lungs, stomach, or an open wound, for example—there is no thick layer of skin to serve as a barrier and damage results. Alpha-emitting radioactive materials that concentrate as persisting deposits in specific parts of the body are considered very hazardous.

Beta-emitters are generally considered an internal hazard although they also can be classed as an external hazard because they can produce burns when in contact with the skin. They require the same precautions as do alpha-emitters if there is a chance they can become airborne. In addition, some shielding may be required.

**Measuring ionizing radiation.** Many types of meters are used to measure various kinds of ionizing radiation. These

meters must be accurately calibrated for the type of radiation they are designed to measure.

Meters with very thin windows in the probes can be used to check for alpha-radiation. Geiger-Mueller and ionization chamber-type instruments are used for measuring beta-, gamma-, and x-radiation. Special types of meters are available for measuring neutrons.

Devices are available that measure accumulated amounts (doses) of radiation. Film badges are used as dosimeters to record the amount of radiation received from beta-, x-ray, or gamma-radiation and special badges are available to record neutron radiation.

Film badges are worn by a worker continuously during each monitoring period. Depending on how they are worn, they allow an estimate of an accumulated dose of radiation to the whole body or to just a part of the body, such as a hand or arm.

Alpha-radiation cannot be measured with film badges because alpha-particles do not penetrate the paper that must be used over the film emulsion to exclude light. (For more details on measurement and government regulations for ionizing radiation, see Chapter 10, Ionizing Radiation.)

### NONIONIZING RADIATION

This is a form of electromagnetic radiation with varying effects on the body, depending largely on the wavelength of the radiation involved. In the following paragraphs, in approximate order of decreasing wavelength and increasing frequency, are some hazards associated with different regions of the nonionizing electromagnetic radiation spectrum. Nonionizing radiation is covered in detail by OSHA regulations 29 *CFR* 1910.97, and in Chapter 11, Nonionizing Radiation.

**Low frequency.** Longer wavelengths, including powerline transmission frequencies, broadcast radio, and shortwave radio, can produce general heating of the body. The health hazard from these kinds of radiation is very small, however, because it is unlikely that they would be found in intensities great enough to cause significant effect. An exception can be found very close to powerful radio transmitter aerials.

Microwaves are found in radar, communications, some types of cooking, and diathermy applications. Microwave intensities may be sufficient to cause significant heating of tissues.

The effect is related to wavelength, power intensity, and time of exposure. Generally, longer wavelengths produce a greater penetration and temperature rise in deeper tissues than shorter wavelengths. However, for a given power intensity, there is less subjective awareness to the heat from longer wavelengths than there is to the heat from shorter wavelengths, because of the absorption of the longer wavelength radiation beneath the body's surface.

An intolerable rise in body temperature, as well as localized damage to specific organs, can result from an exposure

of sufficient intensity and time. In addition, flammable gases and vapors can ignite when they are inside metallic objects located in a microwave beam.

Infrared radiation does not penetrate below the superficial layer of the skin, so its only effect is to heat the skin and the tissues immediately below it. Except for thermal burns, the health hazard of exposure to low-level conventional infrared radiation sources is negligible. (For information on possible damage to the eye, consult Chapter 11, Nonionizing Radiation.)

Visible radiation, which is about midway in the electromagnetic spectrum, is important because it can affect both the quality and accuracy of work. Good lighting conditions generally result in increased product quality with less spoilage and increased production.

Lighting should be bright enough for easy and efficient sight, and directed so that it does not create glare. Illumination levels and brightness ratios recommended for manufacturing and service industries are published by the Illuminating Engineering Society. (See Chapter 11, Nonionizing Radiation, for further information.)

One of the most objectionable features of lighting is glare (brightness in the field of vision that causes discomfort or interferes with seeing). The brightness can be caused by either direct or reflected light. To prevent glare, the source of light should be kept well above the line of vision or shielded with opaque or translucent material.

Almost as problematic is an area of excessively high brightness in the visual field. A highly reflective white paper in the center of a dark, nonreflecting surface or a brightly illuminated control handle on a dark or dirty machine are two examples.

To prevent such conditions, keep surfaces uniformly light or dark with little difference in surface reflectivity. Color contrasts are acceptable, however.

Although it is generally best to provide even, shadow-free light, some jobs require contrast lighting. In these cases, keep the general (or background) light well diffused and glareless and add a supplementary source of light that casts shadows where needed.

Ultraviolet radiation in industry can be found around electrical arcs, and such arcs should be shielded by materials opaque to ultraviolet. The fact that a material can be opaque to ultraviolet has no relation to its opacity to other parts of the spectrum. Ordinary window glass, for instance, is almost completely opaque to the ultraviolet in sunlight although transparent to the visible wavelengths. A piece of plastic dyed a deep red-violet may be almost entirely opaque in the visible part of the spectrum and transparent in the near-ultraviolet spectrum.

Electric welding arcs and germicidal lamps are the most common strong producers of ultraviolet radiation in industry. The ordinary fluorescent lamp generates a good deal of ultraviolet inside the bulb, but it is essentially all absorbed by the bulb and its coating.

The most common exposure to ultraviolet radiation is from direct sunlight, and a familiar result of overexposure—one that is known to all sunbathers—is sunburn. Most people are familiar with certain compounds and lotions that reduce the effects of the sun's rays, but many are unaware that some industrial materials, such as cresols, make the skin especially sensitive to ultraviolet rays. After exposure to cresols, even a short exposure in the sun usually results in a severe sunburn.

Lasers emit beams of coherent radiation of a single color or wavelength and frequency, in contrast to conventional light sources, which produce random, disordered light wave mixtures of various frequencies. The laser (an acronym for light amplification by stimulated emission of radiation) is made up of light waves that are nearly parallel to each other, all traveling in the same direction. Atoms are “pumped” full of energy, and when they are stimulated to fall to a lower energy level, they give off radiation that is directed to produce the coherent laser beam. (See Chapter 11, Nonionizing Radiation, for more details.)

The maser, the laser's predecessor, emits microwaves instead of light. Some companies call their lasers “optical masers.” Because the laser is highly collimated (has a small divergence angle), it can have a large energy density in a narrow beam. Direct viewing of the laser source or its reflections should be avoided. The work area should contain no reflective surface (such as mirrors or highly polished furniture) because even a reflected laser beam can be hazardous. Suitable shielding to contain the laser beam should be provided. The OSHA Act covers protection against laser hazards in its construction regulations.

**Biological effects.** The eye is the organ that is most vulnerable to injury by laser energy because the cornea and lens focus the parallel laser beam on a small spot on the retina. The fact that infrared radiation of certain lasers may not be visible to the naked eye contributes to the potential hazard.

Lasers generating in the ultraviolet range of the electromagnetic spectrum can produce corneal burns rather than retinal damage, because of the way the eye handles ultraviolet light. (See Chapter 11, Nonionizing Radiation.)

Other factors that affect the degree of eye injury induced by laser light are as follows:

- Pupil size (the smaller the pupil diameter, the less laser energy reaches the retina)
- The ability of the cornea and lens to focus the incident light on the retina
- The distance from the source of energy to the retina
- The energy and wavelength of the laser
- The pigmentation of the eye of the subject
- The location on the retina where the light is focused
- The divergence of the laser light
- The presence of scattering media in the light path

A discussion of laser beam characteristics and protective eyewear can be found in Chapter 11.

## EXTREMES OF PRESSURE

It has been recognized from the beginning of caisson work (work performed in a watertight structure) that people working under pressures greater than normal atmospheric pressure are subject to various health effects. *Hyperbaric* (greater than normal pressure) environments are also encountered by divers who work under water, whether by holding the breath while diving, breathing from a self-contained underwater breathing apparatus (SCUBA), or by breathing gas mixtures supplied by compression from the surface.

Occupational exposures occur in caisson or tunneling operations, where a compressed gas environment is used to exclude water or mud and to provide support for structures. Humans can withstand large pressures if air has free access to lungs, sinuses, and the middle ear. Unequal distribution of pressure can result in barotrauma, a kind of tissue damage resulting from expansion or contraction of gas spaces within or adjacent to the body, which can occur either during compression (descent) or during decompression (ascent).

The teeth, sinuses, and ears are often affected by pressure differentials. For example, gas spaces adjacent to tooth roots or fillings may be compressed during descent. Fluid or tissue forced into these spaces can cause pain during descent or ascent. Sinus blockage caused by occlusion of the sinus aperture by inflamed nasal mucosa prevents equalization of pressures.

Under some conditions of work at high pressure, the concentration of carbon dioxide in the atmosphere can be considerably increased so that the carbon dioxide acts as a narcotic. Keeping the oxygen concentration high minimizes this condition, but does not prevent it. The procedure is useful where the carbon dioxide concentration cannot be kept at a proper level.

Decompression sickness, commonly called the bends, results from the release of nitrogen bubbles into the circulation and tissues during decompression. If the bubbles lodge at the joints and under muscles, they cause severe cramps. To prevent this, decompression is carried out slowly and by stages so that the nitrogen can be eliminated slowly, without forming bubbles.

Deep-sea divers are supplied with a mixture of helium and oxygen for breathing, and because helium is an inert diluent and less soluble in blood and tissue than is nitrogen, it presents a less formidable decompression problem.

One of the most common troubles encountered by workers under compressed air is pain and congestion in the ears from inability to ventilate the middle ear properly during compression and decompression. As a result, many workers subjected to increased air pressures suffer from temporary hearing loss; some have permanent hearing loss. This damage is believed to be caused by obstruction of the eustachian tubes, which prevents proper equalization of pressure from the throat to the middle ear.

The effects of reduced pressure on the worker are much the same as the effects of decompression from a high pressure. If

pressure is reduced too rapidly, decompression sickness and ear disturbances similar to the diver's conditions can result.

## Ergonomic Hazards

*Ergonomics* literally means the study or measurement of work. It is the application of human biological science in conjunction with the engineering sciences to achieve the optimum mutual adjustment of people to their work, the benefits being measured in terms of human efficiency and well-being. The topic of ergonomics is covered briefly here. (For more details, see Chapter 13, Ergonomics.)

The ergonomics approach goes beyond productivity, health, and safety. It includes consideration of the total physiological and psychological demands of the job on the worker.

In the broad sense, the benefits that can be expected from designing work systems to minimize physical stress on workers are as follows:

- > Reduced incidence of repetitive motion disorders
- > Reduced injury rate
- > More efficient operation
- > Fewer accidents
- > Lower cost of operation
- > Reduced training time
- > More effective use of personnel

The human body can endure considerable discomfort and stress and can perform many awkward and unnatural movements for a limited period of time. However, when awkward conditions or motions are continued for prolonged periods, they can exceed the worker's physiological limitations. To ensure a continued high level of performance, work systems must be tailored to human capacities and limitations.

Ergonomics considers the physiological and psychological stresses of the task. The task should not require excessive muscular effort, considering the worker's age, sex, and state of health. The job should not be so easy that boredom and inattention lead to unnecessary errors, material waste, and accidents. Ergonomic stresses can impair the health and efficiency of the worker just as significantly as the more commonly recognized environmental stresses.

The task of the design engineer and health and safety professional is to find the happy medium between "easy" and "difficult" jobs. In any human-machine system, there are tasks that are better performed by people than by machines and, conversely, tasks that are better handled by machines.

Ergonomics deals with the interactions between humans and such traditional environmental elements as atmospheric contaminants, heat, light, sound, and tools and equipment. People are the monitoring link of a human-machine environment system.

In any activity, a person receives and processes information, and then acts on it. The receptor function occurs largely through the sense organs of the eyes and the ear, but information can also be conveyed through the senses of smell, touch, or sensations of heat or cold. This information

is conveyed to the central mechanism of the brain and spinal cord, where the information is processed to arrive at a decision. This can involve the integration of the information, which has already been stored in the brain, and decisions can vary from automatic responses to those involving a high degree of reasoning and logic.

Having received the information and processed it, the individual then takes action (control) as a result of the decision, usually through muscular activity based on the skeletal framework of the body. When an individual's activity involves the operation of a piece of equipment, the person often forms part of a "closed-loop servosystem," displaying many of the feedback characteristics of such a system. The person usually forms the part of the system that makes decisions, and thus has a fundamental part to play in the efficiency of the system.

## BIOMECHANICS—PHYSICAL DEMANDS

Biomechanics can be a very effective tool in preventing excessive work stress. *Biomechanics* means the mechanics of biological organisms. It deals with the functioning of the structural elements of the body and the effects of external and internal forces on the various parts of the body.

Cumulative effects of excessive ergonomic stress on the worker can, in an insidious and subtle manner, result in physical illnesses and injuries such as "trigger finger," tenosynovitis, bursitis, carpal tunnel syndrome, and other cumulative trauma disorders.

Cases of excessive fatigue and discomfort are, in many cases, forerunners of soreness and pain. By exerting a strong distracting influence on a worker, these stresses can render the worker more prone to major accidents. Discomfort and fatigue tend to make the worker less capable of maintaining the proper vigilance for the safe performance of the task.

Some of the principles of biomechanics can be illustrated by considering different parts of the human anatomy, such as the hand.

**Hand anatomy.** The flexing action in the fingers is controlled by tendons attached to muscles in the forearm. The tendons, which run in lubricated sheaths, enter the hand through a tunnel in the wrist formed by bones and ligaments (the carpal tunnel) and continue on to point of attachment to the different segments, or phalanges, of the fingers (Figure 1-3).

When the wrist is bent toward the little finger side, the tendons tend to bunch up on one side of the tunnel through which they enter the hand. If an excessive amount of force is continuously applied with the fingers while the wrist is flexed, or if the flexing motion is repeated rapidly over a long period of time, the resulting friction can produce inflammation of the tendon sheaths, or tenosynovitis. This can lead to a disabling condition called carpal tunnel syndrome. (See Chapter 13, Ergonomics.)

The palm of the hand, which contains a network of nerves and blood vessels, should never be used as a hammer or

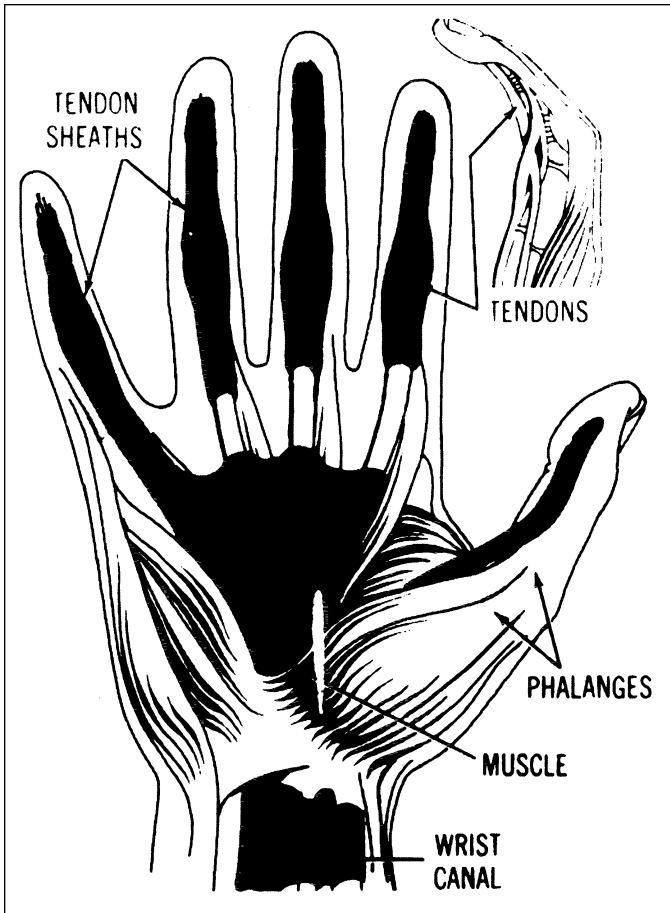


Figure 1-3. Diagram of hand anatomy.

subjected to continued firm pressure. Repetitive or prolonged pressure on the nerves and blood vessels in this area can result in pain either in the palm itself or at any point along the nerve pathways up through the arm and shoulder. Other parts of the body, such as the elbow joints and shoulders, can become painful for similar reasons.

**Mechanical vibration.** A condition known to stonecutters as “dead fingers” or “white fingers” (Raynaud’s phenomenon) occurs mainly in the fingers of the hand used to guide the cutting tool. The circulation in this hand becomes impaired, and when exposed to cold the fingers become white and without sensation, as though mildly frostbitten. The white appearance usually disappears when the fingers are warmed for some time, but a few cases are sufficiently disabling that the victims are forced to seek other types of work. In many instances both hands are affected.

The condition has been observed in a number of other occupations involving the use of vibrating tools, such as the air hammers used for scarfing metal surfaces, the air chisels for chipping castings in the metal trades, and the chain saws used in forestry. The injury is caused by vibration of the fingers as they grip the tools to guide them in performing their

tasks. The related damage to blood vessels can progress to nearly complete obstruction of the vessels.

Prevention should be directed at reducing the vibrational energy transferred to the fingers (perhaps by the use of padding) and by changing the energy and frequency of the vibration. Low frequencies, 25–75 hertz, are more damaging than higher frequencies.

**Lifting.** The injuries resulting from manual handling of objects and materials make up a large proportion of all compensable injuries. This problem is of considerable concern to the health and safety professional and represents an area where the biomechanical data relating to lifting and carrying can be applied in the work layout and design of jobs that require handling of materials. (For more details, see Chapter 13, Ergonomics, and the *Application Manual for the Revised NIOSH Lifting Equation*.)

The relevant data concerning lifting can be classified into task, human, and environmental variables.

> *Task variables*

- Location of object to be lifted
- Size of the object to be lifted
- Height from which and to which the object is lifted
- Frequency of lift
- Weight of object
- Working position

> *Human variables*

- Sex of worker
- Age of worker
- Training of worker
- Physical fitness or conditioning of worker
- Body dimensions, such as height of the worker

> *Environmental variables*

- Extremes of temperature
- Humidity
- Air contaminants

**Static work.** Another very fatiguing situation encountered in industry, which unfortunately is often overlooked, is static, or isometric, work. Because very little outward movement occurs, it seems that no muscular effort is involved. Often, however, such work generates more muscular fatigue than work involving some outward movement. A cramped working posture, for example, is a substantial source of static muscular loading.

In general, maintaining any set of muscles in a rigid, unsupported position for long periods of time results in muscular strain. The blood supply to the contracted muscle is diminished, a local deficiency of oxygen can occur, and waste products accumulate. Alternating static and dynamic work, or providing support for partial relaxation of the member involved, alleviates this problem.

Armrests are usually needed in two types of situations. One is the case just mentioned—to relieve the isometric muscular work involved in holding the arm in a fixed, unsupported

position for long periods of time. The second case is where the arm is pressed against a hard surface such as the edge of a bench or machine. The pressure on the soft tissues overlaying the bones can cause bruises and pain. Padded armrests have solved numerous problems of both types (see Figure 1–4).

### WORKPLACE DESIGN

Relating the physical characteristics and capabilities of the worker to the design of equipment and to the layout of the workplace is another key ergonomic concept. When this is done, the result is an increase in efficiency, a decrease in human error, and a consequent reduction in accident frequency. However, several different types of information are needed: a description of the job, an understanding of the kinds of equipment to be used, a description of the kinds of people who will use the equipment, and the biological characteristics of these people.

In general, the first three items—job, equipment, and users—can be defined easily. The biological characteristics of the users, however, can often be determined satisfactorily only from special surveys that yield descriptive data on human body size and biomechanical abilities and limitations.

**Anthropometric data.** Anthropometric data consist of various heights, lengths, and breadths used to establish the minimum clearances and spatial accommodations, and the functional arm, leg, and body movements that are made by the worker during the performance of the task.

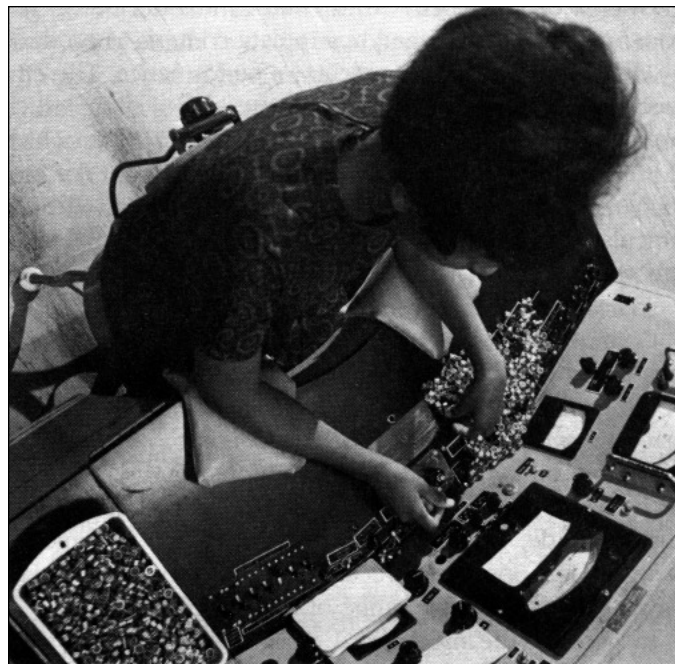
### BEHAVIORAL ASPECTS—MENTAL DEMANDS

One important aspect of industrial machine design directly related to the safety and productivity of the worker is the design of displays and controls.

**Design of displays.** Displays are one of the most common types of operator input; the others include direct sensing and verbal or visual commands. Displays tell the operator what the machine is doing and how it is performing. Problems of display design are primarily related to the human senses.

A machine operator can successfully control equipment only to the extent that the operator receives clear, unambiguous information, when needed on all pertinent aspects of the task. Accidents, or operational errors, often occur because a worker has misinterpreted or was unable to obtain information from displays. Displays are usually visual, although they also can be auditory (for example, a warning bell rather than a warning light), especially when there is danger of overloading the visual sensory channels.

**Design of Controls.** An operator must decide on the proper course of action and manipulate controls to produce any desired change in the machine's performance. The efficiency and effectiveness—that is, the safety with which controls can be operated—depend on the extent to which information on the dynamics of human movement (or biomechanics) has been



**Figure 1–4.** Worker uses pads to keep her forearm off the sharp table edge.

incorporated in their design. This is particularly true whenever controls must be operated at high speed, against large resistances, with great precision, or over long periods of time.

Controls should be designed so that rapid, accurate settings easily can be made without undue fatigue, thereby avoiding many accidents and operational errors. Because there is a wide variety of machine controls, ranging from the simple on–off action of pushbuttons to very complex mechanisms, advance analysis of the task requirements must be made. On the basis of considerable experimental evidence, it is possible to recommend the most appropriate control and its desirable range of operation.

In general, the mechanical design of equipment must be compatible with the biological and psychological characteristics of the operator. The effectiveness of the human–machine combination can be greatly enhanced by treating the operator and the equipment as a unified system. Thus, the instruments should be considered as extensions of the operator's nervous and perceptual systems, the controls as extensions of the hands, and the feet as simple tools. Any control that is difficult to reach or operate, any instrument dial that has poor legibility, any seat that induces poor posture or discomfort, or any obstruction of vision can contribute directly to an accident or illness.

### Biological Hazards

Approximately 200 biological agents, such as infectious microorganisms, biological allergens, and toxins, are known to produce infections or allergic, toxic, or carcinogenic reactions in workers. Most of the identified biohazardous agents belong to these groups:

- Microorganisms and their toxins (viruses, bacteria, fungi, and their products) resulting in infection, exposure, or allergy
- Arthropods (crustaceans, arachnids, insects) associated with bites or stings resulting in skin inflammation, systemic intoxication and transmission of infectious agents, or allergic response
- Allergens and toxins from higher plants, producing dermatitis, rhinitis, or asthma
- Protein allergens (such as urine, feces, hair, saliva, and dander) from vertebrate animals

Other groups with the potential to expose workers to biohazards include lower plants other than fungi (lichen, liverworts, ferns) and invertebrate animals other than arthropods (parasites such as protozoa, *Schistosoma*) and roundworms (*Ascaris*).

Workers engaging in agricultural, medical, and laboratory work have been identified as most at risk to occupational biohazards but many varied workplaces present the potential for such exposure. For example, at least 24 of the 150 zoonotic diseases known worldwide are considered to be a hazard for agricultural workers in North America. Risk of infection varies with the type and species of animal and geographic location. Disease may be contracted directly from animals, but more often it is acquired in the workplace environment. Controls include awareness of specific hazards, use of personal protective equipment, preventive veterinary care, worker education, and medical monitoring or prophylactic therapy, where appropriate.

The potential for exposure to occupational biohazards exists in most work environments. The following are but a few examples in very diverse workplaces:

- Workers maintaining water systems can be exposed to *Legionella pneumophila* and *Naegleria spp.*
- Workers associated with birds (parrots, parakeets, pigeons) in pet shops, aviaries, or on construction and public works jobs near perching or nesting sites can be exposed to *Chlamydia psittaci*.
- Workers in wood processing facilities can be exposed to endotoxins, allergenic fungi growing on timber, and fungi causing deep mycoses.
- Sewage and compost workers can be exposed to enteric bacteria, hepatitis A virus, infectious or endotoxin-producing bacteria, parasitic protozoa, and allergenic fungi.
- Health care workers, emergency responders, law enforcement officers, and morticians may be exposed to such bloodborne pathogens as hepatitis B (HBV), hepatitis C (HCV), and the human immunodeficiency virus (HIV) in addition to other biological hazards. (See Chapter 14, Biological Hazards.)

#### **BUILDING-RELATED ILLNESSES DUE TO BIOLOGICAL HAZARDS**

The sources of biological hazards may be fairly obvious in occupations associated with the handling of microorganisms, plants, and animals and in occupations involving contact with potentially infected people. However, recognizing and identi-

fying biological hazards may not be as simple in other situations such as office buildings and nonindustrial workplaces. Building-related illness (BRI) is a clinically diagnosed disease in one or more building occupants, as distinguished from sick-building syndrome (SBS), in which building occupants' non-specific symptoms cannot be associated with an identifiable cause. Certain BRI such as infectious and hypersensitivity diseases are clearly associated with biological hazards, but the role of biological materials in SBS is not as well understood.

The conditions and events necessary to result in human exposure to bioaerosols are the presence of a reservoir that can support the growth of microorganisms or allow accumulation of biological material, multiplication of contaminating organisms or biological materials in the reservoir, generation of aerosols containing biological material, and exposure of susceptible workers. (See Chapter 14, Biological Hazards, for a full discussion.)

#### **INDUSTRIAL SANITATION—WATER SUPPLY**

The requirements for sanitation and personal facilities are covered in the OSHA safety and health regulations 29 *CFR* 1910, Subpart J—General Environmental Controls. The OSHA regulations for carcinogens require special personal health and sanitary facilities for employees working with potentially carcinogenic materials.

Potable water should be provided in workplaces when needed for drinking and personal washing, cooking, washing of foods or utensils, washing of food preparation premises, and personal service rooms.

Drinking fountain surfaces must be constructed of materials impervious to water and not subject to oxidation. The nozzle of the fountain must be located to prevent the return of water in the jet or bowl to the nozzle orifice. A guard over the nozzle prevents contact with the nozzle by the mouth or nose of people using the drinking fountain.

Potable drinking water dispensers must be designed and constructed so that sanitary conditions are maintained; they must be capable of being closed and equipped with a tap. Ice that comes in contact with drinking water must be made of potable water and maintained in a sanitary condition. Standing water in cooling towers and other air-moving systems should be monitored for legionella bacteria. (See Chapter 14, Biological Hazards, for details.)

Outlets for nonpotable water, such as water for industrial or firefighting purposes, must be marked in a manner that indicates clearly that the water is unsafe and is not to be used as drinking water. Nonpotable water systems or systems carrying any other nonpotable substance should be constructed so as to prevent backflow or backsiphonage.

#### **HARMFUL AGENTS—ROUTE OF ENTRY**

In order to exert its toxic effect, a harmful agent must come into contact with a body cell and must enter the body via inhalation, skin absorption, or ingestion.

Chemical compounds in the form of liquids, gases, mists, dusts, fumes, and vapors can cause problems by inhalation (breathing), absorption (through direct contact with the skin), or ingestion (eating or drinking).

## Inhalation

Inhalation involves airborne contaminants that can be inhaled directly into the lungs and can be physically classified as gases, vapors, and particulate matter including dusts, fumes, smokes, aerosols, and mists.

Inhalation, as a route of entry, is particularly important because of the rapidity with which a toxic material can be absorbed in the lungs, pass into the bloodstream, and reach the brain. Inhalation is the major route of entry for hazardous chemicals in the work environment.

## Absorption

Absorption through the skin can occur quite rapidly if the skin is cut or abraded. Intact skin, however, offers a reasonably good barrier to chemicals. Unfortunately, there are many compounds that can be absorbed through intact skin.

Some substances are absorbed by way of the openings for hair follicles and others dissolve in the fats and oils of the skin, such as organic lead compounds, many nitro compounds, and organic phosphate pesticides. Compounds that are good solvents for fats (such as toluene and xylene) also can be absorbed through the skin.

Many organic compounds, such as TNT, cyanides, and most aromatic amines, amides, and phenols, can produce systemic poisoning by direct contact with the skin.

## Ingestion

In the workplace, people can unknowingly eat or drink harmful chemicals. Toxic compounds can be absorbed from the gastrointestinal tract into the blood. Lead oxide can cause serious problems if people working with this material are allowed to eat or smoke in work areas. Thorough washing is required both before eating and at the end of every shift.

Inhaled toxic dusts can also be ingested in hazardous amounts. If the toxic dust swallowed with food or saliva is not soluble in digestive fluids, it is eliminated directly through the intestinal tract. Toxic materials that are readily soluble in digestive fluids can be absorbed into the blood from the digestive system.

It is important to study all routes of entry when evaluating the work environment—candy bars or lunches in the work area, solvents being used to clean work clothing and hands, in addition to airborne contaminants in working areas. (For more details, see Chapter 6, Industrial Toxicology.)

## TYPES OF AIRBORNE CONTAMINANTS

There are precise meanings of certain words commonly used in industrial hygiene. These must be used correctly in order to understand the requirements of OSHA regulations,

effectively communicate with other occupational health professionals, recommend or design and test appropriate engineering controls, and correctly prescribe personal protective equipment. For example, a fume respirator is worthless as protection against gases or vapors. Too often, terms (such as gases, vapors, fumes, and mists) are used interchangeably. Each term has a definite meaning and describes a certain state of matter.

## States of Matter

Matter is divided into dusts, fumes, smoke, aerosols, mists, gases, and vapors. These are discussed in the following sections.

### DUSTS

These are solid particles generated by handling, crushing, grinding, rapid impact, detonation, and decrepitation (breaking apart by heating) of organic or inorganic materials, such as rock, ore, metal, coal, wood, and grain.

*Dust* is a term used in industry to describe airborne solid particles that range in size from 0.1–25  $\mu\text{m}$  in diameter (1  $\mu\text{m}$  = 0.0001 cm or 1/25,400 in.). Dusts more than 5  $\mu\text{m}$  in size usually do not remain airborne long enough to present an inhalation problem (see Chapter 8, Particulates).

Dust can enter the air from various sources, such as when a dusty material is handled (as when lead oxide is dumped into a mixer or talc is dusted on a product). When solid materials are reduced to small sizes in processes such as grinding, crushing, blasting, shaking, and drilling, the mechanical action of the grinding or shaking device supplies energy to disperse the dust.

Evaluating dust exposures properly requires knowledge of the chemical composition, particle size, dust concentration in air, how it is dispersed, and many other factors described here. Although in the case of gases, the concentration that reaches the alveolar sacs is nearly like the concentration in the air breathed, this is not the case for aerosols or dust particles. Large particles, more than 10  $\mu\text{m}$  aerodynamic diameter, can be deposited through gravity and impaction in large ducts before they reach the very small sacs (alveoli). Only the smaller particles reach the alveoli. (See Chapter 2, The Lungs, for more details.)

Except for some fibrous materials, dust particles must usually be smaller than 5  $\mu\text{m}$  in order to penetrate to the alveoli or inner recess of the lungs.

A person with normal eyesight can detect dust particles as small as 50  $\mu\text{m}$  in diameter. Smaller airborne particles can be detected individually by the naked eye only when strong light is reflected from them. Particles of dust of respirable size (less than 10  $\mu\text{m}$ ) cannot be seen without the aid of a microscope, but they may be perceived as a haze.

Most industrial dusts consist of particles that vary widely in size, with the small particles greatly outnumbering the large ones. Consequently (with few exceptions), when dust is noticeable in the air near a dusty operation, probably more invisible dust particles than visible ones are present. A

process that produces dust fine enough to remain suspended in the air long enough to be breathed should be regarded as hazardous until it can be proved safe.

There is no simple one-to-one relationship between the concentration of an atmospheric contaminant and duration of exposure and the rate of dosage by the hazardous agent to the critical site in the body. For a given magnitude of atmospheric exposure to a potentially toxic particulate contaminant, the resulting hazard can range from an insignificant level to one of great danger, depending on the toxicity of the material, the size of the inhaled particles, and other factors that determine their fate in the respiratory system.

### FUMES

These are formed when the material from a volatilized solid condenses in cool air. The solid particles that are formed make up a fume that is extremely fine, usually less than 1.0  $\mu\text{m}$  in diameter. In most cases, the hot vapor reacts with the air to form an oxide. Gases and vapors are not fumes, although the terms are often mistakenly used interchangeably.

Welding, metalizing, and other operations involving vapors from molten metals may produce fumes; these may be harmful under certain conditions. Arc welding volatilizes metal vapor that condenses as the metal or its oxide in the air around the arc. In addition, the rod coating is partially volatilized. These fumes, because they are extremely fine, are readily inhaled.

Other toxic fumes, such as those formed when welding structures that have been painted with lead-based paints or when welding galvanized metal, can produce severe symptoms of toxicity rather rapidly unless fumes are controlled with effective local exhaust ventilation or the welder is protected by respiratory protective equipment.

Fortunately, most soldering operations do not require temperatures high enough to volatilize an appreciable amount of lead. However, the lead in molten solder pots is oxidized by contact with air at the surface. If this oxide, often called dross, is mechanically dispersed into the air, it can produce a severe lead-poisoning hazard.

In operations when lead dust may be present in air, such as soldering or lead battery-making, preventing occupational poisoning is largely a matter of scrupulously clean house-keeping to prevent the lead oxide from becoming dispersed into the air. It is customary to enclose melting pots, dross boxes, and similar operations, and to ventilate them adequately to control the hazard. Other controls may be necessary as well.

### SMOKE

This consists of carbon or soot particles less than 0.1  $\mu\text{m}$  in size, and results from the incomplete combustion of carbonaceous materials such as coal or oil. Smoke generally contains droplets as well as dry particles. Tobacco, for instance, produces a wet smoke composed of minute tarry droplets.

### AEROSOLS

These are liquid droplets or solid particles of fine enough particle size to remain dispersed in air for a prolonged period of time.

### MISTS

These are suspended liquid droplets generated by condensation of liquids from the vapor back to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing, foaming, or atomizing. The term *mist* is applied to a finely divided liquid suspended in the atmosphere. Examples are the oil mist produced during cutting and grinding operations, acid mists from electroplating, acid or alkali mists from pickling operations, paint spray mist in painting operations, and the condensation of water vapor to form a fog or rain.

### GASES

These are formless fluids that expand to occupy the space or enclosure in which they are confined. Gases are a state of matter in which the molecules are unrestricted by cohesive forces. Examples are arc-welding gases, internal combustion engine exhaust gases, and air.

### VAPORS

These are the volatile form of substances that are normally in the solid or liquid state at room temperature and pressure. Evaporation is the process by which a liquid is changed into the vapor state and mixed with the surrounding atmosphere. Solvents with low boiling points volatilize readily at room temperature.

In addition to the definitions concerning states of matter that are used daily by industrial hygienists, terms used to describe degree of exposure include the following:

- > ppm: parts of vapor or gases per million parts of air by volume at room temperature and pressure
- > mppcf: millions of particles of a particulate per cubic foot of air
- >  $\text{mg}/\text{m}^3$ : milligrams of a substance per cubic meter of air
- > f/cc: fibers of a substance per cubic centimeter of air

The health and safety professional recognizes that air contaminants exist as a gas, dust, fume, mist, or vapor in the workroom air. In evaluating the degree of exposure, the measured concentration of the air contaminant is compared to limits or exposure guidelines that appear in the published standards on levels of exposure (see Appendix B).

## Respiratory Hazards

Airborne chemical agents that enter the lungs can pass directly into the bloodstream and be carried to other parts of the body. The respiratory system consists of organs contributing to normal respiration or breathing. Strictly speaking, it includes the nose, mouth, upper throat, larynx, trachea, and bronchi (which are all air passages or airways) and the lungs, where oxygen is passed into the blood and carbon dioxide is given off. Finally, it includes the

diaphragm and the muscles of the chest, which perform the normal respiratory movements of inspiration and expiration. (See Chapter 2, The Lungs.)

All living cells of the body are engaged in a series of chemical processes; the sum total of these processes is called metabolism. In the course of its metabolism, each cell consumes oxygen and produces carbon dioxide as a waste product.

Respiratory hazards can be broken down into two main groups:

- > Oxygen deficiency, in which the oxygen concentration (or partial pressure of oxygen) is below the level considered safe for human exposure
- > Air that contains harmful or toxic contaminants

### OXYGEN-DEFICIENT ATMOSPHERES

Each living cell in the body requires a constant supply of oxygen. Some cells are more dependent on a continuing oxygen supply than others. Some cells in the brain and nervous system can be injured or die after 4–6 min without oxygen. These cells, if destroyed, cannot be regenerated or replaced, and permanent changes and impaired functioning of the brain can result from such damage. Other cells in the body are not as critically dependent on an oxygen supply because they can be replaced.

Normal air at sea level contains approximately 21 percent oxygen and 79 percent nitrogen and other inert gases. At sea level and normal barometric pressure (760 mmHg or 101.3 kPa), the partial pressure of oxygen would be 21 percent of 760 mm, or 160 mm. The partial pressure of nitrogen and inert gases would be 600 mm (79 percent of 760 mm).

At higher altitudes or under conditions of reduced barometric pressure, the relative proportions of oxygen and nitrogen remain the same, but the partial pressure of each gas is decreased. The partial pressure of oxygen at the alveolar surface of the lung is critical because it determines the rate of oxygen diffusion through the moist lung tissue membranes.

Oxygen-deficient atmospheres may exist in confined spaces as oxygen is *consumed* by chemical reactions such as oxidation (rust, fermentation), *replaced* by inert gases such as argon, nitrogen, and carbon dioxide, or *absorbed* by porous surfaces such as activated charcoal.

Deficiency of oxygen in the atmosphere of confined spaces can be a problem in industry. For this reason, the oxygen content of any tank or other confined space (as well as the levels of any toxic contaminants) should be measured before entry is made. Instruments are commercially available for this purpose. (See Chapter 16, Air Sampling, Chapter 17, Direct-Reading Instruments for Gases, Vapors, and Particulates, and Chapter 22, Respiratory Protection, for more details.)

The first physiological signs of an oxygen deficiency (anoxia) are an increased rate and depth of breathing. A worker should never enter or remain in areas where tests have indicated oxygen deficiency without a supplied-air or self-contained respirator that is specifically approved by NIOSH

for those conditions. (See Chapter 22, Respiratory Protection, for more details.)

Oxygen-deficient atmospheres can cause an inability to move and a semiconscious lack of concern about the imminence of death. In cases of abrupt entry into areas containing little or no oxygen, the person usually has no warning symptoms, immediately loses consciousness, and has no recollection of the incident if rescued in time to be revived. The senses cannot be relied on to alert or warn a person of atmospheres deficient in oxygen.

Oxygen-deficient atmospheres can occur in tanks, vats, holds of ships, silos, mines, or in areas where the air may be diluted or displaced by asphyxiating levels of gases or vapors, or where the oxygen may have been consumed by chemical or biological reactions.

Ordinary jobs involving maintenance and repair of systems for storing and transporting fluids or entering tanks or tunnels for cleaning and repairs are controlled almost entirely by the immediate supervisor. The supervisor should be particularly knowledgeable of all rules and precautions to ensure the safety of those who work in such atmospheres. Safeguards should be meticulously observed.

For example, there should be a standard operating procedure for entering tanks. Such procedures should be consistent with OSHA regulations and augmented by in-house procedures, which may enhance the basic OSHA rules. The American National Standards Institute (ANSI) lists confined space procedures in its respiratory protection standard and NIOSH has also issued guidelines for work in confined spaces (see Bibliography). Even if a tank is empty, it may have been closed for some time and developed an oxygen deficiency through chemical reactions of residues left in the tank. It may be unsafe to enter without proper respiratory protection.

### THE HAZARD OF AIRBORNE CONTAMINANTS

Inhaling harmful materials can irritate the upper respiratory tract and lung tissue, or the terminal passages of the lungs and the air sacs, depending on the solubility of the material.

Inhalation of biologically inert gases can dilute the atmospheric oxygen below the normal blood saturation value and disturb cellular processes. Other gases and vapors may prevent the blood from carrying oxygen to the tissues or interfere with its transfer from the blood to the tissue, producing chemical asphyxia.

Inhaled contaminants that adversely affect the lungs fall into three general categories:

- > Aerosols (particulates), which, when deposited in the lungs, can produce either rapid local tissue damage, some slower tissue reactions, eventual disease, or physical plugging
- > Toxic vapors and gases that produce adverse reaction in the tissue of the lungs

➤ Some toxic aerosols or gases that do not affect the lung tissue locally but pass from the lungs into the bloodstream, where they are carried to other body organs or have adverse effects on the oxygen-carrying capacity of the blood cells

An example of an aerosol is silica dust, which causes fibrotic growth (scar tissue) in the lungs. Other harmful aerosols are fungi found in sugar cane residues, producing bagassosis.

An example of the second type of inhaled contaminant is hydrogen fluoride, a gas that directly affects lung tissue. It is a primary irritant of mucous membranes, even causing chemical burns. Inhalation of this gas causes pulmonary edema and direct interference with the gas transfer function of the alveolar lining.

An example of the third type of inhaled contaminant is carbon monoxide, a toxic gas passed into the bloodstream without harming the lung. The carbon monoxide passes through the alveolar walls into the blood, where it ties up the hemoglobin so that it cannot accept oxygen, thus causing oxygen starvation. Cyanide gas has another effect—it prevents enzymatic utilization of molecular oxygen by cells.

Sometimes several types of lung hazards occur simultaneously. In mining operations, for example, explosives release oxides of nitrogen. These impair the bronchial clearance mechanism so that coal dust (of the particle sizes associated with the explosions) is not efficiently cleansed from the lungs.

If a compound is very soluble—such as ammonia, sulfuric acid, or hydrochloric acid—it is rapidly absorbed in the upper respiratory tract and during the initial phases of exposure does not penetrate deeply into the lungs. Consequently, the nose and throat become very irritated.

Compounds that are insoluble in body fluids cause considerably less throat irritation than the soluble ones, but can penetrate deeply into the lungs. Thus, a very serious hazard can be present and not be recognized immediately because of a lack of warning that the local irritation would otherwise provide. Examples of such compounds (gases) are nitrogen dioxide and ozone. The immediate danger from these compounds in high concentrations is acute lung irritation or, possibly, chemical pneumonia.

There are numerous chemical compounds that do not follow the general solubility rule. Such compounds are not very soluble in water and yet are very irritating to the eyes and respiratory tract. They also can cause lung damage and even death under certain conditions. (See Chapter 6, Industrial Toxicology.)

## THRESHOLD LIMIT VALUES

The ACGIH Threshold Limit Values® (TLVs®) are exposure guidelines established for airborne concentrations of many chemical compounds. The health and safety professional or other responsible person should understand something about TLVs and the terminology in which their concentra-

tions are expressed. (See Chapter 15, Evaluation, Chapter 6, Industrial Toxicology, and Appendix B for more details.)

TLVs are airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect. Control of the work environment is based on the assumption that for each substance there is some safe or tolerable level of exposure below which no significant adverse effect occurs. These tolerable levels are called Threshold Limit Values. In its Introduction, the ACGIH *Threshold Limit Values (TLVs®) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs®)* states that because individual susceptibility varies widely, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit. A smaller percentage may be affected more seriously by aggravation of a preexisting condition or by development of an occupational illness. Smoking may enhance the biological effects of chemicals encountered in the workplace and may reduce the body's defense mechanisms against toxic substances.

Hypersusceptible individuals or those otherwise unusually responsive to some industrial chemicals because of genetic factors, age, personal habits (smoking and use of alcohol or other drugs), medication, or previous exposures may not be adequately protected from adverse health effects of chemicals at concentrations at or below the threshold limits.

These limits are not fine lines between safe and dangerous concentration, nor are they a relative index of toxicity. They should not be used by anyone untrained in the discipline of industrial hygiene.

The copyrighted trademark *Threshold Limit Value®* refers to limits published by ACGIH. The TLVs are reviewed and updated annually to reflect the most current information on the effects of each substance assigned a TLV. (See Appendix B and the Bibliography of this chapter.)

The data for establishing TLVs come from animal studies, human studies, and industrial experience, and the limit may be selected for several reasons. As mentioned earlier in this chapter, the TLV can be based on the fact that a substance is very irritating to the majority of people exposed, or the fact that a substance is an asphyxiant. Still other reasons for establishing a TLV for a given substance include the fact that certain chemical compounds are anesthetic or fibrogenic or can cause allergic reactions or malignancies. Some additional TLVs have been established because exposure above a certain airborne concentration is a nuisance.

The amount and nature of the information available for establishing a TLV varies from substance to substance; consequently, the precision of the estimated TLV continues to be subject to revision and debate. The latest documentation for that substance should be consulted to assess the present data available for a given substance.

In addition to the TLVs set for chemical compounds, there are limits for physical agents such as noise,

radiofrequency/microwave radiation, segmental vibration, lasers, ionizing radiation, static magnetic fields, light, near-infrared radiation, subradiofrequency ( $\leq 30$  kHz) magnetic fields, subradiofrequency and static electric fields, ultraviolet radiation, cold stress, and heat stress. There are also biological exposure indices (BEIs<sup>®</sup>). (See Chapter 9, Industrial Noise, Chapter 11, Nonionizing Radiation, and Appendix B.)

The ACGIH periodically publishes a documentation of TLVs<sup>®</sup> in which it gives the data and information on which the TLV for each substance is based. This documentation can be used to provide health and safety professionals with insight to aid professional judgment when applying the TLVs.

The most current edition of the ACGIH *Threshold Limit Values (TLVs<sup>®</sup>) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs<sup>®</sup>)* should be used. When referring to an ACGIH TLV, the year of publication should always preface the value, as in “the 2001 TLV for nitric oxide was 25 ppm.” Note that the TLVs are not mandatory federal or state employee exposure standards, and the term *TLV* should not be used for standards published by OSHA or any agency except the ACGIH.

Three categories of Threshold Limit Values are specified as follows:

#### TIME-WEIGHTED AVERAGE (TLV–TWA)

This is the time-weighted average concentration for a conventional eight-hour workday and 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.

#### SHORT-TERM EXPOSURE LIMIT (TLV–STEL)

This is the concentration to which it is believed workers can be exposed continuously for a short period of time without suffering from:

- > Irritation
- > Chronic or irreversible tissue damage
- > Narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or materially reduce work efficiency and provided that the daily TLV–TWA is not exceeded

A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday, even if the eight-hour TWA is within the TLV–TWA. Exposures above the TLV–TWA up to the STEL should not be longer than 15 min and should not occur more than four times per day. There should be at least 60 min between successive exposures in this range.

The TLV–STEL is not a separate, independent exposure limit; it supplements the TWA limit when there are recognized acute effects from a substance that has primarily chronic effects. The STELs are recommended only when toxic effects in humans or animals have been reported from high short-term exposures.

*Note:* None of the limits mentioned here, especially the TWA–STEL, should be used as engineering design criteria.

#### CEILING (TLV–C)

This is the concentration that should not be exceeded during any part of the working exposure. To assess a TLV–C if instantaneous monitoring is not feasible, the conventional industrial hygiene practice is to sample during a 15-min period, except for substances that can cause immediate irritation with short exposures.

For some substances (such as irritant gases), only one category, the TLV–C, may be relevant. For other substances, two or three categories may be relevant, depending on their physiological action. If any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

Limits based on physical irritation should be considered no less binding than those based on physical impairment. Increasing evidence shows that physical irritation can initiate, promote, or accelerate physical impairment via interaction with other chemical or biological agents.

The amount by which threshold limits can be exceeded for short periods without injury to health depends on many factors: the nature of the contaminant; whether very high concentrations, even for a short period, produce acute poisoning; whether the effects are cumulative; the frequency with which high concentrations occur; and the duration of such periods. All factors must be considered when deciding whether a hazardous condition exists.

#### Skin Notation

A number of the substances in the TLV list are followed by the designation *Skin*. This refers to potential significant exposure through the cutaneous route, including mucous membranes and the eyes, either by contact with vapors or, of probably greater significance, by direct skin contact with the substance. Vehicles such as certain solvents can alter skin absorption. This designation is intended to suggest appropriate measures for the prevention of cutaneous absorption.

#### Mixtures

Special consideration should be given in assessing the health hazards that can be associated with exposure to mixtures of two or more substances.

#### Federal Occupational Safety and Health Standards

The first compilation of the health and safety standards promulgated by OSHA in 1970 was derived from the then-existing federal standards and national consensus standards. Thus, many of the 1968 TLVs established by the ACGIH became federal standards or permissible exposure limits (PELs). Also, certain workplace quality standards known as ANSI maximal acceptable concentrations were incorporated as federal health standards in 29 *CFR* 1910.1000 (Table Z–2) as national consensus standards.

In adopting the ACGIH TLVs, OSHA also adopted the concept of the TWA for a workday. In general:

$$\text{TWA} = \frac{C_a T_a + C_b T_b + \dots + C_n T_n}{8}$$

where  $T_a$  = the time of the first exposure period during the shift

$C_a$  = the concentration of contaminant in period  $a$

$T_b$  = another time period during the shift

$C_b$  = the concentration during period  $b$

$T_n$  = the  $n$ th or final time period in the shift

$C_n$  = the concentration during period  $n$

This simply provides a summation throughout the workday of the product of the concentrations and the time periods for the concentrations encountered in each time interval and averaged over an 8-hour standard workday.

## EVALUATION

Evaluation can be defined as the decision-making process resulting in an opinion on the degree of health hazard posed by chemical, physical, biological, or ergonomic stresses in industrial operations. The basic approach to controlling occupational disease consists of evaluating the potential hazard and controlling the specific hazard by suitable industrial hygiene techniques. (See Chapter 15, Evaluation, for more details.)

Evaluation involves judging the magnitude of the chemical, physical, biological, or ergonomic stresses. Determining whether a health hazard exists is based on a combination of observation, interviews, and measurement of the levels of energy or air contaminants arising from the work process as well as an evaluation of the effectiveness of control measures in the workplace. The industrial hygienist then compares environmental measurements with hygienic guides, TLVs, OSHA PELs, NIOSH RELs, or reports in the literature.

Evaluation, in the broad sense, also includes determining the levels of physical and chemical agents arising out of a process to study the related work procedures and to determine the effectiveness of a given piece of equipment used to control the hazards from that process.

Anticipating and recognizing industrial health hazards involve knowledge and understanding of the several types of workplace environmental stresses and the effects of these stresses on the health of the worker. Control involves the reduction of environmental stresses to values that the worker can tolerate without impairment of health or productivity. Measuring and quantitating environmental stress are the essential ingredients for modern industrial hygiene, and are instrumental in conserving the health and well-being of workers.

### Basic Hazard-Recognition Procedures

There is a basic, systematic procedure for recognizing and evaluating environmental health hazards, which includes the following questions:

> What is produced?

- > What raw material is used?
- > What materials are added in the process?
- > What equipment is involved?
- > What is the cycle of operations?
- > What operational procedures are used?
- > Is there a written procedure for the safe handling and storage of materials?
- > What about dust control, cleanup after spills, and waste disposal?
- > Are the ventilating and exhaust systems adequate?
- > Does the facility layout minimize exposure?
- > Is the facility well-equipped with safety appliances such as showers, masks, respirators, and emergency eyewash fountains?
- > Are safe operating procedures outlined and enforced?
- > Is a complete hazard communication program that meets state or federal OSHA requirements in effect?

Understand the industrial process well enough to see where contaminants are released. For each process, perform the following:

- > For each contaminant, find the OSHA PEL or other safe exposure guideline based on the toxicological effect of the material.
- > Determine the actual level of exposure to harmful physical agents.
- > Determine the number of employees exposed and length of exposure.
- > Identify the chemicals and contaminants in the process.
- > Determine the level of airborne contaminants using air-sampling techniques.
- > Calculate the resulting daily average and peak exposures from the air-sampling results and employee exposure times.
- > Compare the calculated exposures with OSHA standards, the TLV listing published by the ACGIH, the NIOSH RELs, the hygienic guides, or other toxicological recommendations.

All of the above are discussed in detail in the following chapters.

### Information Required

Detailed information should be obtained regarding types of hazardous materials used in a facility, the type of job operation, how the workers are exposed, work patterns, levels of air contamination, duration of exposure, control measures used, and other pertinent information. The hazard potential of the material is determined not only by its inherent toxicity, but also by the conditions of use (who uses what, where, and how long?).

To recognize hazardous environmental factors or stresses, a health and safety professional must first know the raw materials used and the nature of the products and by-products manufactured. Consult MSDSs for the substances.

Any person responsible for maintaining a safe, healthful work environment should be thoroughly acquainted with the concen-

trations of harmful materials or energies that may be encountered in the industrial environment for which they are responsible.

If a facility is going to handle a hazardous material, the health and safety professional must consider all the unexpected events that can occur and determine what precautions are required in case of an accident to prevent or control atmospheric release of a toxic material.

After these considerations have been studied and proper countermeasures installed, operating and maintenance personnel must be taught the proper operation of the health and safety control measures. Only in this way can personnel be made aware of the possible hazards and the need for certain built-in safety features.

The operating and maintenance people should set up a routine procedure (at frequent, stated intervals) for testing the emergency industrial hygiene and safety provisions that are not used in normal, ordinary facility or process operations.

### Degree of Hazard

The degree of hazard from exposure to harmful environmental factors or stresses depends on the following:

- > Nature of the material or energy involved
- > Intensity of the exposure
- > Duration of the exposure

The key elements to be considered when evaluating a health hazard are how much of the material in contact with body cells is required to produce injury, the probability of the material being absorbed by the body to result in an injury, the rate at which the airborne contaminant is generated, the total time of contact, and the control measures in use.

### Air Sampling

The importance of the sampling location, the proper time to sample, and the number of samples to be taken during the course of an investigation of the work environment cannot be overstressed.

Although this procedure might appear to be a routine, mechanical job, actually it is an art requiring detailed knowledge of the sampling equipment and its shortcomings. The person taking the sample(s) needs to know where and when to sample; and how to weigh the many factors that can influence the sample results, such as ambient temperature, season of the year, unusual problems in work operations, and interference from other contaminants. The sample must usually be taken in the breathing zone of an employee (see Figure 1–5).

The air volume sampled must be sufficient to permit a representative determination of the contaminant to properly compare the result with the TLV or PEL. The sampling period must usually be sufficient to give a direct measure of the average full-shift exposure of the employees concerned. The sample must be sealed and identified if it is to be shipped to a laboratory so that it is possible to identify positively the time and place of sampling and the individual who took the sample.



**Figure 1–5.** Portable pump with intake positioned to collect continuous samples from the breathing zone of an employee. (Courtesy MSA)

Area samples, taken by setting the sampling equipment in a fixed position in the work area, are useful as an index of general contamination. However, the actual exposure of the employee at the point of generation of the contaminant can be greater than is indicated by an area sample.

To meet the requirement of establishing the TWA concentrations, the sampling method and time periods should be chosen to average out fluctuations that commonly occur in a day's work. If there are wide fluctuations in concentration, the long-term samples should be supplemented by samples designed to catch the peaks separately.

If the exposure being measured is from a continuous operation, it is necessary to follow the particular operator through two cycles of operation, or through the full shift if operations follow a random pattern during the day. For operations of this sort, it is particularly important to find out what the workers do when the equipment is down for maintenance or process change. Such periods are often also periods of maximum exposure. (See Chapter 16, Air Sampling.)

As an example of the very small concentrations involved, the industrial hygienist commonly samples and measures substances in the air of the working environment in concentrations ranging from 1 to 100 ppm. Some idea of the magnitude of these concentrations can be appreciated when one realizes that 1 inch in 16 miles is 1 part per million; 1 cent in \$10,000, 1 ounce of salt in 62,500 pounds of sugar, and

1 ounce of oil in 7,812.5 gallons of water all represent 1 part per million.

## OCCUPATIONAL SKIN DISEASES

Some general observations on dermatitis are given in this chapter, but more detailed information is given in Chapter 3, The Skin and Occupational Dermatoses. Occupational dermatoses can be caused by organic substances, such as formaldehyde, solvents or inorganic materials, such as acids and alkalis, and chromium and nickel compounds. Skin irritants are usually either liquids or dusts.

### Types

There are two general types of dermatitis: primary irritation and sensitization.

#### PRIMARY IRRITATION DERMATITIS

Nearly all people suffer primary irritation dermatitis from mechanical agents such as friction, from physical agents such as heat or cold, and from chemical agents such as acids, alkalis, irritant gases, and vapors. Brief contact with a high concentration of a primary irritant or prolonged exposure to a low concentration causes inflammation. Allergy is not a factor in these conditions.

#### SENSITIZATION DERMATITIS

This type results from an allergic reaction to a given substance. The sensitivity becomes established during the induction period, which may be a few days to a few months. After the sensitivity is established, exposure to even a small amount of the sensitizing material is likely to produce a severe reaction.

Some substances can produce both primary irritation dermatitis and sensitization dermatitis. Among them are organic solvents, chromic acid, and epoxy resin systems.

### Causes

Occupational dermatitis can be caused by chemical, mechanical, physical, and biological agents and plant poisons.

Chemical agents are the predominant causes of dermatitis in manufacturing industries. Cutting oils and similar substances are significant because the oil dermatitis they cause is probably of greater interest to industrial concerns than is any other type of dermatitis.

*Detergents* and solvents remove the natural oils from the skin or react with the oils of the skin to increase susceptibility to reactions from chemicals that ordinarily do not affect the skin. Materials that remove the natural oils include alkalis, soap, and turpentine.

*Dessicators*, hygroscopic agents, and anhydrides take water out of the skin and generate heat. Examples are sulfur dioxide and trioxide, phosphorus pentoxide, strong acids such as sulfuric acid, and strong alkalis such as potash.

*Protein precipitants* tend to coagulate the outer layers of the skin. They include all the heavy metallic salts and those

that form alkaline albuminates on combining with the skin, such as mercuric and ferric chloride. Alcohol, tannic acid, formaldehyde, picric acid, phenol, and intense ultraviolet rays are other examples of protein-precipitating agents.

*Oxidizers* unite with hydrogen and liberate nascent oxygen on the skin. Such materials include nitrates, chlorine, iodine, bromine, hypochlorites, ferric chloride, hydrogen peroxide, chromic acid, permanganates, and ozone.

*Solvents* extract essential skin constituents. Examples are ketones, aliphatic and aromatic hydrocarbons, halogenated hydrocarbons, ethers, esters, and certain nitro compounds.

*Allergic or anaphylactic proteins* stimulate the production of antibodies that cause skin reactions in sensitive people. The sources of these antigens are usually cereals, flour, and pollens, but can include feathers, scales, flesh, fur, and other emanations.

*Mechanical* causes of skin irritation include friction, pressure, and trauma, which may facilitate infection with either bacteria or fungi.

*Physical agents* leading to occupational dermatitis include heat, cold, sunlight, x rays, ionizing radiation, and electricity. The x rays and other ionizing radiation can cause dermatitis, severe burns, and even cancer. Prolonged exposure to sunlight produces skin changes and may cause skin cancer.

*Biological agents* causing dermatitis can be bacterial, fungal, or parasitic. Boils and folliculitis caused by staphylococci and streptococci, and general infection from occupational wounds, are probably the best known among the bacterial skin infections. These can be occupationally induced infections.

*Fungi* cause athlete's foot and other types of dermatitis among kitchen workers, bakers, and fruit handlers; fur, hide, and wool handlers or sorters; barbers; and horticulturists. Parasites cause grain itch and often occur among handlers of grains and straws, and particularly among farmers, laborers, miners, fruit handlers, and horticulturists.

*Plant poisons* causing dermatitis are produced by several hundred species of plants. The best known are poison ivy, poison oak, and poison sumac. Dermatitis from these three sources can result from bodily contact with any part of the plant, exposure of any part of the body to smoke from the burning plant, or contact with clothing or other objects previously exposed to the plant.

## Physical Examinations

Preplacement examinations help identify those especially susceptible to skin irritations. The examining physician should be given detailed information on the type of work for which the applicant is being considered. If the work involves exposure to skin irritants, the physician should determine whether the prospective employee has deficiencies or characteristics likely to predispose him or her to dermatitis (see Chapter 25, The Occupational Medicine Physician, for more details).

## Preventive Measures

Before new or different chemicals are introduced in an established process, possible dermatitis hazards should be carefully considered. Once these hazards are anticipated, suitable engineering controls should be devised and built into the processes to avoid them.

The type, number, and amounts of skin irritants used in various industrial processes affect the degree of control that can be readily obtained, but the primary objective in every case should be to eliminate skin contact as completely as possible. The preventive measures discussed in Chapter 18, Methods of Control, can be adapted to control industrial dermatitis.

## CONTROL METHODS

With employment in the United States shifting from manufacturing to the service sector, many workplaces today present nontraditional occupational health hazards. Industrial hygienists need to possess the skills to implement control methodology in both industrial settings and in workplaces such as laboratories, offices, health care facilities, and environmental remediation projects. Hazards can change with time as well, so that hazard control systems require continual review and updating.

Control methods for health hazards in the work environment are divided into three basic categories:

1. Engineering controls that engineer out the hazard, either by initial design specifications or by applying methods of substitution, isolation, enclosure, or ventilation. In the hierarchy of control methods, the use of engineering controls should be considered first.
2. Administrative controls that reduce employee exposures by scheduling reduced work times in contaminant areas (or during cooler times of the day for heat stress exposure, for example). Also included here is employee training that includes hazard recognition and specific work practices that help reduce exposure. (This type of training is required by law for all employees exposed to hazardous materials in the course of their work.)
3. Personal protective equipment the employees wear to protect them from their environment. Personal protective equipment includes anything from gloves to full body suits with self-contained breathing apparatus, and can be used in conjunction with engineering and administrative controls.

Engineering controls should be used as the first line of defense against workplace hazards wherever feasible. Such built-in protection, inherent in the design of a process, is preferable to a method that depends on continual human implementation or intervention. The federal regulations, and their interpretation by the Occupational Safety and Health Review commission, mandate the use of engineering controls to the extent feasible; if they are not sufficient to achieve acceptable limits of exposure, the use of personal

protective equipment and other corrective measures may be considered.

Engineering controls include ventilation to minimize dispersion of airborne contaminants, isolation of a hazardous operation or substance by means of barriers or enclosures, and substitution of a material, equipment, or process to provide hazard control. Although administrative control measures can limit the duration of individual exposures, they are not generally favored by employers because they are difficult to implement and maintain. For similar reasons, control of health hazards by using respirators and protective clothing is usually considered secondary to the use of engineering control methods. (See Chapter 18, Methods of Control.)

## Engineering Controls

Substituting or replacing a toxic material with a harmless one is a very practical method of eliminating an industrial health hazard. In many cases, a solvent with a lower order of toxicity or flammability can be substituted for a more hazardous one. In a solvent substitution, it is always advisable to experiment on a small scale before making the new solvent part of the operation or process.

A change in process often offers an ideal chance to improve working conditions as well as quality and production. In some cases, a process can be modified to reduce the hazard. Brush painting or dipping instead of spray painting minimizes the concentration of airborne contaminants from toxic pigments. Structural bolts in place of riveting, steam-cleaning instead of vapor degreasing of parts, and airless spraying techniques and electrostatic devices to replace hand-spraying are examples of process change. In buying individual machines, the need for accessory ventilation, noise and vibration suppression, and heat control should be considered before the purchase.

Noisy operations can be isolated from the people nearby by a physical barrier (such as an acoustic box to contain noise from a whining blower or a rip saw). Isolation is particularly useful for limited operations requiring relatively few workers or where control by any other method is not feasible.

Enclosing the process or equipment is a desirable method of control because it can minimize escape of the contaminant into the workroom atmosphere. Examples of this type of control are glove box enclosures and abrasive shot blast machines for cleaning castings.

In the chemical industry, isolating hazardous processes in closed systems is a widespread practice. The use of a closed system is one reason why the manufacture of toxic substances can be less hazardous than their use.

Dust hazards often can be minimized or greatly reduced by spraying water at the source of dust dispersion. "Wetting down" is one of the simplest methods for dust control. However, its effectiveness depends on proper wetting of the dust and keeping it moist. To be effective, the addition of a wetting agent to the water and proper and timely disposal of the wetted dust before it dries out and is redispersed may be necessary.

## Ventilation

The major use of exhaust ventilation for contaminant control is to prevent health hazards from airborne materials. OSHA has ventilation standards for abrasive blasting, grinding, polishing and buffing operations, spray finishing operations, and open-surface tanks. For more details, see Chapter 19, Local Exhaust Ventilation, and Chapter 20, Dilution Ventilation of Industrial Workplaces.

A local exhaust system traps and removes the air contaminant near the generating source, which usually makes this method much more effective than general ventilation. Therefore, local exhaust ventilation should be used when exposures to the contaminant cannot be controlled by substitution, changing the process, isolation, or enclosure. Even though a process has been isolated, it still may require a local exhaust system.

General or dilution ventilation—removing and adding air to dilute the concentration of a contaminant to below hazardous levels—uses natural or forced air movement through open doors, windows, roof ventilators, and chimneys. General exhaust fans can be mounted in roofs, walls, or windows (see Chapters 19 and 20 for more details).

Consideration must be given to providing replacement air, especially during winter. Dilution ventilation is feasible only if the quantity of air contaminant is not excessive, and is particularly effective if the contaminant is released at a substantial distance from the worker's breathing zone. General ventilation should not be used where there is a major, localized source of contamination (especially highly toxic dusts and fumes). A local exhaust system is more effective in such cases.

Air conditioning does not substitute for air cleaning. Air conditioning is mainly concerned with control of air temperature and humidity and can be accomplished by systems that accomplish little or no air cleaning. An air-conditioning system usually uses an air washer to accomplish temperature and humidity control, but these air washers are not designed as efficient air cleaners and should not be used as such. (See Chapter 21, General Ventilation of Nonindustrial Occupancies.)

Processes in which materials are crushed, ground, or transported are potential sources of dust dispersion, and should be controlled either by wet methods or enclosed and ventilated by local exhaust ventilation. Points where conveyors are loaded or discharged, transfer points along the conveying system, and heads or boots of elevators should be enclosed as well as ventilated. (For more details, see Chapter 19, Local Exhaust Ventilation.)

## Personal Protective Equipment

When it is not feasible to render the working environment completely safe, it may be necessary to protect the worker from that environment by using personal protective equipment. This is considered a secondary control method to engineering and administrative controls and should be used as a last resort.

Where it is not possible to enclose or isolate the process or equipment, ventilation or other control measures should be provided. Where there are short exposures to hazardous concentrations of contaminants and where unavoidable spills may occur, personal protective equipment must be provided and used.

Personal protective devices have one serious drawback: They do nothing to reduce or eliminate the hazard. They interpose a barrier between worker and hazard; if the barrier fails, immediate exposure is the result. The supervisor must be constantly alert to make sure that required protective equipment is worn by workers who need supplementary protection, as may be required by OSHA standards. (See Chapter 22, Respiratory Protection.)

## Administrative Controls

When exposure cannot be reduced to permissible levels through engineering controls, as in the case of air contaminants or noise, an effort should be made to limit the employee's exposure through administrative controls.

Examples of some administrative controls are as follows:

- Arranging work schedules and the related duration of exposures so that employees are minimally exposed to health hazards
- Transferring employees who have reached their upper permissible limits of exposure to an environment where no further additional exposure will be experienced

Where exposure levels exceed the PEL for one worker in one day, the job can be assigned to two, three, or as many workers as needed to keep each one's duration of exposure within the PEL. In the case of noise, other possibilities may involve intermittent use of noisy equipment.

Administrative controls must be designed only by knowledgeable health and safety professionals, and used cautiously and judiciously. They are not as satisfactory as engineering controls and have been criticized by some as a means of spreading exposures instead of reducing or eliminating the exposure.

Good housekeeping plays a key role in occupational health protection. Basically, it is a key tool for preventing dispersion of dangerous contaminants and for maintaining safe and healthful working conditions. Immediate cleanup of any spills or toxic material, by workers wearing proper protective equipment, is a very important control measure. Good housekeeping is also essential where solvents are stored, handled, and used. Leaking containers or spigots should be fixed immediately, and spills cleaned promptly. All solvent-soaked rags or absorbents should be placed in airtight metal receptacles and removed daily.

It is impossible to have an effective occupational health program without good maintenance and housekeeping. Workers should be informed about the need for these controls. Proper training and education are vital elements for successful implementation of any control effort, and are required by law as part of a complete federal or state OSHA hazard communication program. (See Chapter 18, Methods of Control.)

## SOURCES OF HELP

Specialized help is available from a number of sources. Every supplier of products or services is likely to have competent professional staff who can provide technical assistance or guidance. Many insurance companies that carry workers' compensation insurance provide industrial hygiene consultation services, just as they provide periodic safety inspections.

Professional consultants and privately owned laboratories are available on a fee basis for concentrated studies of a specific problem or for a facilitywide or companywide survey, which can be undertaken to identify and catalog individual environmental exposures. Lists of certified analytical laboratories and industrial hygiene consultants are available from the AIHA.

Many states have excellent industrial hygiene departments that can provide consultation on a specific problem. Appendix A, Additional Resources, contains names and addresses of state and national health and hygiene agencies. NIOSH has a Technical Information Center that can provide information on specific problems. Scientific and technical societies that can help with problems are listed in Appendix A. Some provide consultation services to nonmembers; they all have much accessible technical information. A list of organizations concerned with industrial hygiene is included in Appendix A.

## SUMMARY

No matter what health hazards are encountered, the approach of the industrial hygienist is essentially the same. Using methods relevant to the problem, he or she secures qualitative and quantitative estimates of the extent of hazard. These data are then compared with the recommended exposure guidelines. If a situation hazardous to life or health is shown, recommendations for correction are made. The industrial hygienist's recommendations place particular emphasis on effectiveness of control, cost, and ease of maintenance of the control measures.

Anticipation, recognition, evaluation, and control are the fundamental concepts of providing all workers with a healthy working environment.

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