OCCUPATIONAL SAFETY AND HEALTH SERIES

The National Safety Council Press’ Occupational Safety and Health Series is composed of materials written to help readers establish and maintain safety, health, and environmental programs. These books contain the latest information on establishing priorities, collecting and analyzing data to help identify problems, and developing methods and procedures to reduce or eliminate illness and incidents, thus mitigating injury and minimizing economic loss resulting from these events.

• Accident Prevention Manual for Business & Industry—a volume set
  1. Administration & Programs
  2. Engineering & Technology
  3. Security Management
  4. Environmental Management
• Study Guide: Accident Prevention Manual for Business & Industry: Administration & Programs and Engineering & Technology
• Occupational Health & Safety
• Fundamentals of Industrial Hygiene
• Study Guide: Fundamentals of Industrial Hygiene

In addition to the Occupational Safety and Health Series, some recent NSC Press additions include:
• Authentic Involvement
• Pocket Guide to Safety Essentials
• Injury Facts (formerly Accident Facts®) published annually
• Safety Culture and Effective Safety Management
• Safety Through Design
• On-Site Emergency Response Planning Guide
• Safety and Health Classics
• Lockout/Tagout: The Process of Controlling Hazardous Energy
• Supervisors’ Safety Manual
• Out in Front: Effective Supervision in the Workplace
## Contents

<table>
<thead>
<tr>
<th>Foreword</th>
<th>vii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>ix</td>
</tr>
</tbody>
</table>

### Part I History and Development

| 1 Overview of Industrial Hygiene | 3 |

### Part II Anatomy, Physiology, and Pathology

| 2 The Lungs | 35 |
| 3 The Skin and Occupational Dermatoses | 51 |
| 4 The Ears | 83 |
| 5 The Eyes | 99 |

### Part III Recognition of Hazards

| 6 Industrial Toxicology | 123 |
| 7 Gases, Vapors, and Solvents | 149 |
| 8 Particulates | 169 |
| 9 Industrial Noise | 207 |
| 10 Ionizing Radiation | 257 |
| 11 Nonionizing Radiation | 281 |
| 12 Thermal Stress | 327 |
| 13 Ergonomics | 357 |
| 14 Biological Hazards | 419 |

### Part IV Evaluation of Hazards

| 15 Evaluation | 487 |
| 16 Air Sampling | 523 |
| 17 Direct-Reading Instruments for Gases, Vapors, and Particulates | 561 |

### Part V Control of Hazards

| 18 Methods of Control | 585 |
| 19 Local Exhaust Ventilation | 607 |
| 20 Dilution Ventilation of Industrial Workplaces | 631 |
| 21 General Ventilation of Nonindustrial Occupancies | 643 |
| 22 Respiratory Protection | 667 |
## CONTENTS

### Part VI  Occupational Health and Safety Professions

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>The Industrial Hygienist</td>
<td>727</td>
</tr>
<tr>
<td>24</td>
<td>The Safety Professional</td>
<td>743</td>
</tr>
<tr>
<td>25</td>
<td>The Occupational Medicine Physician</td>
<td>765</td>
</tr>
<tr>
<td>26</td>
<td>The Occupational Health Nurse</td>
<td>775</td>
</tr>
<tr>
<td>27</td>
<td>The Industrial Hygiene Program</td>
<td>793</td>
</tr>
</tbody>
</table>

### Part VII  Government Regulations and Their Impact

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Government Regulations</td>
<td>807</td>
</tr>
<tr>
<td>29</td>
<td>History of the Federal Occupational Safety and Health Administration</td>
<td>825</td>
</tr>
</tbody>
</table>

### Appendices: available online for no access charge at [http://www.nsc.org/nscpress/fih](http://www.nsc.org/nscpress/fih)

- A Additional Resources
- B ACGIH Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®)
- C Conversion of Units
- D Review of Mathematics
- E Glossary

### Index

1049
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
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 Venilation 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
The imperative 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®) and Biological Exposure Indices (BEIs®), 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, ScD
3—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
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 Hygienist—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

xii
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 Kracicsin, 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.

BARBARA A. PLOG, MPH, CIH, CSP
EDITOR IN CHIEF
DECEMBER 2001
Contributors

John R. Balmes, MD, is a Professor of Medicine at the University of California, San Francisco (UCSF) where he is the Chief of the Division of Occupational and Environmental Medicine at San Francisco General Hospital, Director of the Occupational Medicine Residency program, and an Attending Physician on the Pulmonary/Critical Care Service at San Francisco General Hospital. Dr. Balmes leads an active research program involving controlled human exposure studies of the respiratory effects of ambient air pollutants in his Human Exposure Laboratory at the UCSF Lung Biology Center. He also collaborates on several epidemiological projects involving the effects of air pollution on respiratory health at the University of California-Berkeley where he is Director of the Northern California Center for Occupational and Environmental Health.

Thomas E. Bernard, PhD, CIH, joined the University of South Florida faculty in 1989. He offers classes in the industrial hygiene program with major responsibilities for ergonomics, physical agents and controls. His active research programs involve the evaluation of heat stress and strain, the role of clothing in heat stress assessment, and ergonomics. He also tries to promote the practice of industrial hygiene through active participation in professional associations. Previously, he worked for Westinghouse Electric Corporation and the United States Bureau of Mines.

Barbara J. Burgel, RN, MS, COHN-S, FAAN, is a Clinical Professor and Adult Nurse Practitioner in the Department of Community Health Systems at the University of California San Francisco School of Nursing. Ms. Burgel has taught in the Occupational Health Nursing graduate program since 1981. Ms. Burgel is currently providing clinical care and ergonomic interventions to Asian immigrant garment workers in a free clinic in the Oakland, California, Chinatown district.

C. Lyle Cheever CIH-ret, MS, MBA, is retired from Argonne National Laboratory where his work from 1957 to 1998 included project manager for decommissioning of radioactive materials facilities, radioactive and hazardous waste manager, associate director of Occupational Health and Safety, and Industrial Hygiene supervisor.

Richard Cohen, MD, MPH, is a Clinical Professor of Medicine at the University of California, San Francisco. He also lectures at Stanford University School of Medicine. Dr. Cohen is board certified in both Occupational Medicine and
General Preventive Medicine. He has been a member of the CAL/OSHA PEL Advisory Committee and is a Fellow in the American College of Occupational and Environmental Medicine. He provides expertise in industrial toxicology and occupational medicine to industry, particularly in the pharmaceutical, biotechnology and electronics sectors.

Craig E. Colton, CIH, is a Certified Industrial Hygienist in the Regulatory Affairs and Training group of the 3M Occupational Health and Environmental Safety Division with 22 years of experience specializing in respiratory protection. His responsibilities as a senior technical service specialist include conducting workplace protection factor studies on 3M respirators, monitoring and responding to regulatory affairs related to respiratory protection, and providing technical assistance to respirator users. Before joining the 3M staff, he was an instructor at the OSHA Training Institute where he was course chair for respiratory protection. He also quantitatively fit tested OSHA personnel. Colton has also taught continuing education courses for the University of North Carolina and University of California-Berkeley. He is a past chair of the AIHA Respiratory Protection Committee, and America's Section of the International Society for Respiratory Protection, and was a member of the ANSI Z88.12 subcommittee for Respiratory Protection for Infectious Aerosols. He is currently a member of the ANSI Z88 Committee for Respiratory Protection.

Marjorie De Groot received her Masters Degree in Audiology from the University of Colorado in 1985. She has worked in various medical settings performing both diagnostic and rehabilitative audiology. Currently Ms. De Groot is employed at the San Francisco General Occupational Health Service as director of the Hearing Conservation Program. She is a member of the American Academy of Audiology, the California Academy of Audiology and the National Hearing Conservation Association.

Diane O. Fleming, Ph.D, CBSP (ABSA), became active in biosafety and infection-control in the late 1970s at Wright State University in Ohio, as Chairman of their Institutional Biosafety Committee. She served as Biosafety Officer and Assistant Director of Safety for the Johns Hopkins University and Medical Center, and as Biosafety Manager for Frederick Cancer Research and Development Center, Sterling Drug, and Merck & Co, Inc.. Dr. Fleming is now an independent biosafety consultant for academic, government and industrial clients. She is the past-president of ABSA and two local affiliates, ChABSA and MABSA. From 1990–97, she was Chairman of the ASM subcommittee on Laboratory Safety. Diane has published articles in peer-reviewed journals and chapters in books dealing with biosafety. She is co-editor of the third edition of Biological Safety: Principles and Practices, published by the ASM.

Gabriel J. Gillotti is the Director of the Voluntary Programs and Outreach Unit in the U.S. Department of Labor's Region IX Office of OSHA located in San Francisco, California. Mr. Gillotti received a Bachelor of Science degree in Civil Engineering and a Bachelor of Arts degree in Mathematics in 1959 from the University of Notre Dame, Notre Dame, Indiana. He spent four years as a construction engineer for the California Department of Water Resources working on the California Aqueduct system, followed by a number of years as a safety engineer with the California State Division of Industrial Safety and the Boeing Company. In 1970, he joined the U.S. Department of Labor as an industry representative on a Task Force assigned the responsibility to draft and publish safety and health standards and compliance regulations under the Construction Safety and the OSHA Acts of 1969 and 1970 respectively. Since 1971 he has been an adminis-
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.

Deborah Gold is a Senior Industrial Hygienist at Cal/OSHA. She is a member of the ACGIH and the APHA.

Elizabeth Gross is Director of Environmental Health and Safety at Dana-Farber Cancer Institute in Boston, a biomedical research and clinical facility. Prior to working at Dana-Farber, she was Assistant Industrial Hygienist at Harvard University. In both capacities, she has evaluated and helped control a broad range of potential exposures to workers. In addition, Ms. Gross is a Visiting Lecturer at both Harvard and Boston University Schools of Public Health, where she lectures on Fundamentals of Industrial Hygiene, Laboratory, Hospital, and Office Health and Safety. She has also been an active participant in the American Industrial Hygiene Association, the Harvard School of Public Health Industrial Hygiene Program Advisory Board, the American Board of Industrial Hygiene, the Academy of Industrial Hygiene, and the Joint Industrial Hygiene Ethics Education Committee. She is a CIH, has an MS in Industrial Hygiene Ethics Education Committee. She is a CIH, has an MS in Industrial Hygiene Ethics Education Committee. She is a CIH, has an MS in Industrial Hygiene Ethics Education Committee. She is a CIH, has an MS in Industrial Hygiene Ethics Education Committee. She is a CIH, has an MS in Industrial Hygiene Ethics Education Committee. She is a CIH, has an MS in Industrial Hygiene Ethics Education Committee.

Rolf M.A. Hahne, PhD, CIH, is Director, Environmental Health Laboratory and Lecturer, Department of Environmental Health, School of Public Health and Community Medicine, University of Washington. He received his BS from Stanford University, an MA from Columbia University, and a PhD from the University of Wisconsin. He has been working in industrial hygiene and environmental health for 29 years in both the public and private sectors, including work with the Dow Chemical Company, Pan American World Airways, the University of Iowa, and the University of Washington.

S. Katharine Hammond, PhD, CIH, is Professor of Environmental Health Sciences at the University of California-Berkeley School of Public Health. Dr. Hammond directs the industrial hygiene program at University of California-Berkeley. She is a chemist; her research focuses on exposure assessment for epidemiological studies. She has developed new methods for collecting and analyzing chemicals in the workplace and assessing exposures without airborne measurements. Among the major research projects are the relationship between diesel exhaust and lung cancer among railroad workers; the rates of spontaneous abortion among women who work in wafer fabricating clean rooms and their exposures to a variety of chemical, physical and ergonomic agents; respiratory health effects of automobile assembly work; methods to reduce workers’ exposure to lead during bridge rehabilitation; unintended consequences of environmental regulations on occupational exposures; environmental tobacco smoke exposure in the workplace and elsewhere.

A. Lynn Harding, B.Sc., MPH, CBSP (ABSA), is an independent biosafety consultant, has extensive experience working with corporate and academic institutions to develop, implement, and evaluate biosafety programs, facilities, and
training materials. Prior to consulting, she was the Director of the Biological Safety Office and Acting Director of the Environmental Health and Safety Department at Harvard University. Early in her career she worked at several Harvard teaching hospitals, MIT, and the Wright Fleming Institute of Microbiology in London on research associated with nosocomial infections, bacterial vaccine development and folic acid metabolism. An active member of the American Biological Safety Association, she has also served on EPA and RAC taskforces associated with infectious waste and animal and plant containment. She has published on subjects such as laboratory acquired infections, biosafety in research laboratories, infections associated with Hemophilus influenzae, and the development of research tools to study nosocomial infections.

Michael J. Horowitz, MS, CIH, is a District Manager for the California OSHA program. He has been an industrial hygienist with Cal/OSHA for the past 12 years. He is also a second-generation industrial hygienist.

Donna Iverson earned a Bachelor of Arts degree in Geography at the University of California-Berkeley. This has served her well in mapping the dangers and pitfalls inherent in the world of Occupational Safety and Health. She was University of California-Berkeley's Labor Occupational Health Program Librarian for 10 years, and is currently in charge of scheduling and logistics for LOHP's Lead-Safe Schools Training Project.

Sarah Jewell, MD, MPH, is board-certified in Internal Medicine and Occupational/Environmental Medicine. She is an Assistant Clinical Professor of Medicine at the University of California, San Francisco and is the Medical Director of the Occupational Health Service at San Francisco General Hospital.

Rick Kelly MS, CIH, is a Certified Industrial Hygienist. He provides limited consultation services, especially training, course development and writing, such as the “Particulates” chapter, in this edition. In his professional capacity, he provides industrial hygiene services to the Chemistry and Material Sciences and Decontamination and Demolition organizations at Lawrence Livermore National Laboratories.

Prior to this post, Rick was the Supervisor of Industrial Hygiene and Safety at the University of California at Berkeley. He was also the founder and interim director of an EPA-grant initiated health and safety training program at the University of California-Berkeley Extension. He is widely recognized as an expert on peroxidizable chemicals and perchlorate-contaminated ventilation system testing and demolition.

Peggy F. Kivel, CIH, is a Certified Industrial Hygienist with more than 18 years of experience in the field of industrial hygiene. She has served as the Regional Manager for IHI Environmental in the San Francisco Bay Area for the past 12 years. Ms. Kivel has extensive experience in the areas of worker exposure assessments, indoor air quality investigations and hazardous materials management. Prior to working at IHI Environmental, Ms. Kivel was a Staff Industrial Hygienist at IBM Corporation in San Jose, California, providing support for major manufacturing, development and research divisions. She has a Bachelor of Arts degree from the University of California-Berkeley.

Karl H. E. Kroemer, CPE, Ph.D. (Dr.-Ing.) 1965, MS (Dipl.-Ing.) 1960, BS (Vordiplom) 1957, all from the Technical University Hanover, Germany, is Professor Emeritus of Industrial and Systems Engineering, Virginia Tech, Director, Ergonomics Research Institute, Inc. He is a Certified Professional...
Ergonomist, CPE. Fellow, HFES and ES; a member of the AIHA; and an honorary member, International Society for Occupational Ergonomics and Safety. He has written more than 200 publications and obtained two patents. His international consulting experience includes work in engineering anthropometry, applied physiology, biomechanics, human factors engineering, and office ergonomics.

Janet Macher ScD, MPH, is an air pollution research specialist with the California Department of Health Services. She has a Master's Degree from the University of California and doctorate from Harvard University with emphasis on industrial hygiene, public health, and microbiology. Dr. Macher studies engineering measures to control airborne infectious and hypersensitivity diseases, evaluates methods to collect and identify airborne biological material, and participates in investigations of bioaerosol-related illnesses in the state of California.

Barbara Materna, PhD, CIH, has provided industrial hygiene expertise within governmental public health programs at the state and local level since 1981. She is currently Chief of the Occupational Lead Poisoning Prevention Program in the Occupational Health Branch, California Department of Health Services. Her work has been focused on preventing occupational health problems including perchloroethylene exposure in dry cleaning, toxic exposures in wildland firefighting, injuries among refuse collectors, pesticide illness, and occupational lead poisoning. Dr. Materna is also interested in occupational health and safety issues among small business employers, intervention effectiveness, and construction health and safety.

H.J. (Hank) McDermott CIH, CSP, PE, currently is the Team Leader, Occupational Safety & Health, Chevron Research & Technology Co., Richmond, California. He has more than 30 years of safety and industrial hygiene experience in industry and the U.S. Air Force, where he served as a bioenvironmental engineering officer. He has a Bachelor of Science degree in Civil Engineering from the University of Delaware, an Master of Science in Civil Engineering from Northwestern, and an Master of Art in Public Administration from the University of New Mexico. He is the author of the *Handbook of Ventilation for Contaminant Control* (3rd edition), published by the American Conference of Governmental Industrial Hygienists, and is a Fellow of the American Industrial Hygiene Association.

Benjamin W. Mintz is now Professor of Law, Columbus School of Law, the Catholic University of America. He was previously and relevantly Associate Solicitor for Occupational Safety and Health at the U.S. Department of Labor. He published a book, *OSHA: History, Law and Policy* and a number of other articles on OSHA. He is a graduate of the Columbia Law School and also has a rabbinical degree from Yeshivah University.

Linda Morse, MD, is board certified in Occupational Medicine and Chief of Occupational Health Services for Kaiser Permanente San Francisco. She is a Fellow of the American College of Occupational and Environmental Medicine and co-editor of *Occupational Injuries—Evaluation, Management and Prevention*, published by Mosby in 1995. She has lectured and written widely on diverse topics including firefighter health and safety, cumulative trauma disorders of the neck and upper extremity, and the role of the treating physician in the workers' compensation system, and is an Assistant Clinical Professor of Medicine at the University of California, San Francisco, Medical Center.

Jill Niland has more than 20 years of experience in industrial hygiene and occupational health. She is principal consultant and partner in CDIC Chicago, an occupational safety and health consulting firm, which focuses on training.
auditing and program development using new technologies. Previously she was senior industrial hygiene consultant at the National Safety Council in Itasca, Illinois, where she was also an associate editor of the 4th edition of Fundamentals of Industrial Hygiene. In prior positions at Zurich American Insurance, and at Alexander and Alexander, an insurance broker, she provided industrial hygiene services to clients in a wide variety of industries. Ms. Niland received a Bachelor of Arts degree from Cornell University, Ithaca, New York, and a Masters in Public Health degree from the University of Illinois in Chicago.

Elise Pechter, CIH, is a Certified Industrial Hygienist who works for the Occupational Health Surveillance Program at the Massachusetts Department of Public Health. In this capacity she coordinates intervention activities in response to work-related asthma, teen injuries, and acute chemical poisonings, integrating occupational health into public health. A member of ACGIH, NEAIHA, and APHA, Ms. Pechter is on the executive board of the Harriet Hardy Institute, member of the Health/Technical committee of MassCOSH, and chair of the Advisory Board for the Work Environment Justice Fund. In addition, Elise works on several other projects: occupational cancer prevention in an NCI funded small business intervention project, identifying occupational asthma triggers, and providing health and safety training for vocational teachers at an annual conference.

Barbara A Plog, MPH, CIH, CSP, is a Certified Industrial Hygienist and a Certified Safety Professional and has been in the field of occupational health for 20 years. She is the Director of the Continuing Professional Education Program of the Center for Occupational and Environmental Health (COEH) at the University of California-Berkeley School of Public Health. COEH is a NIOSH Education and Research Center. Ms Plog is a Lecturer in the School of Public Health’s industrial hygiene program and an assistant clinical professor at the University of California-San Francisco School of Nursing’s Occupational Health Nursing program. She teaches Industrial Hygiene and Occupational Safety to graduate students in industrial hygiene and occupational health nursing. She also serves as the Associate Director for Technical Services for the Labor Occupational Health Program and is the Technical Director and Principal Investigator for the Lead-Safe Schools Program.

Patricia J. Quinlan, CIH, is a Certified Industrial Hygienist in the Division of Occupational and Environmental Medicine at the University of California, San Francisco. She also holds an appointment as Associate Clinical Professor, in the Department of Community Health Systems, School of Nursing, University of California-San Francisco. Patricia has been active in the field of industrial hygiene for 20 years. She has been with University of California-San Francisco since 1987. Prior to University of California-San Francisco, she was the industrial hygienist for the Labor Occupational Health Program at University of California-Berkeley, from 1982–1987. She is a Certified Industrial Hygienist (CIH) and has been active in a number of committees of the AIHA and APHA Occupational Health Section. She is a member of the California OSHA Statewide Advisory and Airborne Contaminants Advisory Committees.

Susan M. Raterman, CIH, is the founder and President of The Raterman Group, Ltd., an industrial hygiene and environmental hazard consulting firm. The Raterman Group, Ltd. specializes in the areas of comprehensive industrial
hygiene consulting, asbestos and lead hazard assessments and remediation oversight, and indoor air and water quality evaluations. Ms. Raterman provides management and technical expertise in industrial hygiene and environmental health to clients in the commercial, industrial and public sectors. Additionally, she provides compliance program development and training, and expert testimony and litigation support to clients on environmental issues. Ms. Raterman is Certified in the Comprehensive Practice of Industrial Hygiene by the American Industrial Hygiene Association, and is an Illinois Environmental Protection Agency Licensed Industrial Hygienist. She is also a Registered Environmental Property Assessor with the National Registry of Environmental Professionals, and is an Illinois Department of Public Health Licensed Asbestos Building Inspector/Management Planner and Asbestos Project Designer. She attained a Master of Science Degree in Environmental Health Engineering from Northwestern University in Evanston, Illinois, and a Bachelor of Arts in Biology from St. Louis University in St. Louis, Missouri. Ms. Raterman is member of the Advisory Council of Robert D. McCormick School of Engineering and Applied Science of Northwestern University. She is a member of the American Industrial Hygiene Association, the American Board of Industrial Hygiene, the International Facility Management Association, and is on the Board of Directors for Chicago Real Estate Executive Women.

Pete Rice, CIH, has 25 years of experience in developing, implementing, and supervising environmental and occupational safety and industrial hygiene programs. He has participated in the recognition, evaluation, and control of safety and health practices and procedures on hundreds of various industrial, construction, and waste cleanup projects involving chemical, physical, biological, ergonomic, and safety hazards. In addition, Mr. Rice has been partly responsible for developing Cal/OSHA health standards for respiratory protection, ventilation, hazard communication, and asbestos. Mr. Rice most recently managed Harding Lawson Associates’ domestic and international Safety and Industrial Hygiene Programs. Mr. Rice currently serves as the Director for Environmental, Health and Safety Services for ClickSafety (www.clicksafety.com). A leader in distance occupational safety and health learning, Mr. Rice teaches industrial hygiene and safety at the university level (University of California-Berkeley) and has trained numerous industrial hygienists and safety professionals. He formerly acted as the senior technical industrial hygienist, safety professional, and chief training officer for Cal/OSHA. He is Certified Industrial Hygienist - American Board of Industrial Hygiene 1981, No. 2156 Certified Safety Professional - Board of Certified Safety Professionals 1984, No. 7287 Registered Environmental Health Specialist - California 1977, No. 4265 Registered Environmental Assessor - California 1989, No.01050 California Community College Instructor Credential MS, Environmental and Occupational Health and Safety, California State University, Northridge, 1977, Bachelor of Science, Environmental Health and Biology, California State University, Northridge, 1976.

James S. Taylor, MD, is Head, Section of Industrial Dermatology, Cleveland Clinic Foundation. He is a graduate of the Indiana University School of Medicine, completed his dermatology residency at the Cleveland Clinic, is certified by the American Board of Dermatology and previously served as an industrial dermatologist with NIOSH. He is a member of the North American Contact Dermatitis Group, the National Occupational Research Agenda Allergic and Irritant Dermatitis Panel, the AMA Committee to Revise the Guides to the Evaluation of Permanent Impairment, and the Board of Directors of the American Academy of Dermatology. He is past president of the American Contact Dermatitis Society, is the author of 185 scientific publications and serves as a consultant to industry and government.
Vic Toy is a program manager for Global Occupational Health Services for the IBM Corporation. He has been involved with managing industrial hygiene programs and services, setting corporate policies and practices, and most recently, with the implementation of a global occupational health and safety management system. His background spans 20 years of diverse industrial hygiene experience in government and industry. He has delivered a number of presentations at professional meetings and has lectured at San Jose State University and University of California-Berkeley's Labor Occupational Health Program. He is a Fellow of the American Industrial Hygiene Association and a past President of the Academy of Industrial Hygiene. Mr. Toy holds a Bachelor of Science degree in Environmental Sciences from the University of California at Berkeley and a Masters in Public Health in Industrial Hygiene from the University of Michigan. He is certified in Comprehensive Practice by the American Board of Industrial Hygiene and in Management Aspects by the Board of Certified Safety Professionals.

Michael Yost, MS, PhD, is an Associate Professor in the Department of Environmental Health at the University of Washington, as well as the Director of the Industrial Hygiene and Safety program. His interests include optical remote sensing of chemicals in the environment, and physical agents, such as noise, vibration, and nonionizing radiation, in the workplace. Prior to joining the University of Washington in 1993, Dr. Yost was a Research Industrial Hygienist and a Lecturer in the School of Public Health at the University of California-Berkeley. He also served as a Reader at University of California-Berkeley's Department of Electrical Engineering and Computer Sciences. Dr. Yost's current research projects focus on developing novel tools for environmental and occupational exposure assessment. These projects include the development of a workplace open-path Fourier transform infra-red spectroscopy, measurements of pesticide spray aerosols using light detection and ranging, occupational exposures to electromagnetic fields, and noise and vibration exposures in forestry workers.

Allison S. Zaum, OD, MPH, CIH (retired), received a Doctor of Optometry degree from the School of Optometry at the University of California-Berkeley, in 1998. Prior to becoming an optometrist, she worked for many years as an industrial hygienist, both in the pharmaceutical industry and in the semiconductor industry. She received a Masters in Public Health in Environmental Health Sciences from the School of Public Health at the University of California-Berkeley in 1981, and was certified in Comprehensive Practice by the American Board of Industrial Hygiene. Her undergraduate education was at Brandeis University, where she received a Bachelor of Arts in Biology in 1979. Dr. Zaum currently is in private practice.
Part I

HISTORY AND DEVELOPMENT
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
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 AAIIH, 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—often classified, according to the major reaction they produce, as chemical asphyxiants.

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

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
CHAPTER 1 > OVERVIEW OF INDUSTRIAL HYGIENE

Material Safety Data Sheet
May be used to comply with OSHA’s Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List)

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

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.

Section I
Manufacturer’s Name
Emergency Telephone Number
Address (Number, Street, City, State, and ZIP Code)
Telephone Number for Information
Date Prepared
Signature of Preparer (optional)

Section II — Hazardous Ingredients/Identity Information

<table>
<thead>
<tr>
<th>Hazardous Components (Specific Chemical Identity, Common Name(s))</th>
<th>OSHA PEL</th>
<th>ACGIH TLV</th>
<th>Other Limits Recommended</th>
<th>% (optional)</th>
</tr>
</thead>
</table>

Section III — Physical/Chemical Characteristics

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point</td>
<td>Specific Gravity (H₂O = 1)</td>
</tr>
<tr>
<td>Vapor Pressure (mm Hg)</td>
<td>Melting Point</td>
</tr>
<tr>
<td>Vapor Density (AIR = 1)</td>
<td>Evaporation Rate (Butyl Acetate = 1)</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>Appearance and Odor</td>
</tr>
</tbody>
</table>

Section IV — Fire and Explosion Hazard Data

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point (Method Used)</td>
<td>Flammable Limits</td>
</tr>
<tr>
<td></td>
<td>LEL</td>
</tr>
<tr>
<td></td>
<td>UEL</td>
</tr>
</tbody>
</table>

Extinguishing Media

Special Fire Fighting Procedures

Unusual Fire and Explosion Hazards

(Reproduce locally)

OSHA 174, Sept. 1985

Figure 1–2. Material Safety Data Sheet. Its format meets the requirements of the federal hazard communication standard. (Continues)
### Part I ➢ History and Development

#### Section V — Reactivity Data

<table>
<thead>
<tr>
<th>Stability</th>
<th>Unstable</th>
<th>Conditions to Avoid</th>
<th>Stable</th>
</tr>
</thead>
</table>

**Incompatibility (Materials to Avoid)**

**Hazardous Decomposition or Byproducts**

**Hazardous Polymerization**

<table>
<thead>
<tr>
<th>May Occur</th>
<th>Conditions to Avoid</th>
<th>Will Not Occur</th>
</tr>
</thead>
</table>

#### Section VI — Health Hazard Data

**Routes of Entry**

<table>
<thead>
<tr>
<th>Inhalation?</th>
<th>Skin?</th>
<th>Ingestion?</th>
</tr>
</thead>
</table>

**Health Hazards (Acute and Chronic)**

<table>
<thead>
<tr>
<th>Carcinogenicity</th>
<th>NTP?</th>
<th>IARC Monographs?</th>
<th>OSHA Regulated?</th>
</tr>
</thead>
</table>

**Signs and Symptoms of Exposure**

**Medical Conditions Generally Aggravated by Exposure**

**Emergency and First Aid Procedures**

#### Section VII — Precautions for Safe Handling and Use

**Steps to Be Taken in Case Material is Released or Spilled**

**Waste Disposal Method**

**Precautions to Be Taken in Handling and Storing**

**Other Precautions**

#### Section VIII — Control Measures

**Respiratory Protection (Specify Type)**

<table>
<thead>
<tr>
<th>Ventilation</th>
<th>Local Exhaust</th>
<th>Special</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mechanical (General)</td>
<td>Other</td>
</tr>
</tbody>
</table>

**Protective Gloves**

<table>
<thead>
<tr>
<th>Eye Protection</th>
</tr>
</thead>
</table>

**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 OSHAct 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
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 well at first, but develop tolerance rapidly through acclimation) 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.

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:

\[
WBGT_{\text{in}} = 0.7 \, T_{\text{nwb}} + 0.3 \, T_{\text{gt}}
\]

Outdoors with solar load:

\[
WBGT_{\text{out}} = 0.7 \, T_{\text{nwb}} + 0.2 \, T_{\text{gt}} + 0.1 \, T_{\text{db}}
\]

where

- \( T_{\text{nwb}} \) = 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®) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs®) 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 kind 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 classified 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 aerals.

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 OSH 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,” tendosynovitis, 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
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 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, avaries, 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 identifying 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 OSHAct safety and health regulations 29 CFR 1910, Subpart J—General Environmental Controls. The OSHAct 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, smoke, 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 OSHAct 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 μm in diameter (1 μm = 0.0001 cm or 1/25,400 in.). Dusts more than 5 μm 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 μm 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 μm 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 μm 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 μm) 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 µm 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 housekeeping 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 µm 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
- mg/m³: 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 OSHAct regulations and augmented by in-house procedures, which may enhance the basic OSHAct 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 including a criteria document for working 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 concentrations 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 (≤30 kHz) magnetic fields, subradiofrequency and static electric fields, ultraviolet radiation, cold stress, and heat stress. There are also biological exposure indices (BEIs®). (See Chapter 9, Industrial Noise, Chapter 11, Nonionizing Radiation, and Appendix B.)

The ACGIH periodically publishes a documentation of TLVs® 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 (TLV®) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs®) 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:

\[
TWA = \frac{C_a T_a + C_b T_b + \ldots + C_n T_n}{8}
\]

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 is the cycle of operations?
- What materials are added in the process?
- What equipment is used?
- What operational procedures are used?
- What is the nature of the by-products and wastes manufactured?
- Are safe operating procedures outlined and enforced?
- Are there written procedures for the safe handling and storage of materials?
- Are the ventilating and exhaust systems adequate?
- Can the facility minimize exposure?
- Does the facility layout minimize exposure?
- What about dust control, cleanup after spills, and waste disposal?
- Are the facilities equipped with safety appliances such as showers, masks, respirators, and emergency eyewash fountains?
- Is there 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.

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 alkalies, 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, alkalies, 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 alkalies, soap, and turpentine. Desiccators, 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 alkalies 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.)
CHAPTER 1 > OVERVIEW OF INDUSTRIAL HYGIENE

 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.

BIBLIOGRAPHY
 American Conference of Governmental Industrial Hygienists. Threshold Limit Values (TLVs®) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs®). Cincinnati: ACGIH, published annually.
 American National Standards Institute, 1430 Broadway, New York, NY 10017.
 National Institute for Occupational Safety and Health, USDHHS Division of Safety Research. Criteria for a Recommended Standard, Occupational Exposure to Hot Environments,


## Index

### A

Absorption, 21, 55, 125, 498; air sampling, 525; through eye, 108; through hair follicles, 21, 54; gas removal, 617; of ionizing radiation, 279; of neutrons, 263; personal protective equipment for, 690; of radiofrequency and microwave radiation, 297; skin, 690; of solvents, 124, 150; Threshold Limit Value for, 69

Academy of Industrial Hygiene, 739

Acanthamoeba, 109

Acanthoma, 68

Acceptable indoor air quality, 643

Accessible emission limit (AEL), for lasers, 310–11

Accident investigation, 753–54

Accident prevention, 748

Accident report, 754–55

Acclimation, to heat stress, 345, 348

Accrediting Board of Engineering and Technology (ABET), 735, 739

Accumulation (in tissues), 126

Accumulation (in workplace), 587

Acetic acid, 58; sampling method for, 532–36

Acetone, 59, 159

Acetylcholine, 131

Acid: chemical composition of, 158; for disinfection, 440; hazard from, 28, 58, 61, 69, 109, 158;

Acini, 40

Acne, 66–67

Acoustic enclosure, 227

Acoustic trauma, 208

Acquired immune deficiency syndrome (AIDS), 423, 447

Acrolein, 130

Acro-osteolysis, 68

Acrylonitrile, 840, 844

Actinic keratosis, 68

Actinolite, 180, 856, 863
INDEX

Action level (AL), 820, 839, 502
Action limit (AL), for lifting, 383
Action for Smoking and Health, 880; proposed smoking standard opposed by, 866
Activities of daily living (ADL), and impairment guidelines, 72
Activity of ionization, 258
Acute effects (toxicity), 128
Acute exposures (toxicity), 128
Acute-angle closure glaucoma, 106
Adenoid, 37
Adjustability, and workplace design, 373, 394
Administrative control, 30, 496, 586, 597–99; of cold stress, 353; housekeeping, 30, 73; of lasers, 313–15; of noise, 229; OSHA requirements for, 815; of skin hazards, 73.
See also Cleaning and maintenance
Adsorption, 525–27, 617, 680
Advisory Committee on Dangerous Pathogens, 478
Aerodynamic equivalent diameter (AED), 180–81
See also Particulate
Affordance, 359
AFL–CIO, challenges to OSHA by, 829, 830, 837, 842, 851, 853, 855, 856, 859
AFL–CIO v. Brennan, 838
AFL–CIO v. Hodgson, 831
AFL–CIO v. Marshall, 837, 840, 844
Age: and dermatosis, 62; and hearing loss, 89, 90–91, 208, 215, 218; and vision, 102, 104, 106
Agency for Toxic Substances and Disease Registry (ATSDR), 822
Agriculture: and biological hazards, 426; and field sanitation, 854, 857–58; history of OSHA regulation of, 838, 875
AIDS. See Human immunodeficiency virus
Airborne contaminant, effects of, 128–130; hazards of, 23–24. See also Aerosol; Dust; Fume; Gas; Mists; Particulate; Smoke; Vapor
Air cleaner, 30, 680, 615–18
Air conditioning, 346, 645; vs. air cleaning, 30. See also HVAC system
Air conduction, 234
Airflow rate, 633-34, 651–653; design data, 636; fire and explosion prevention, 636–37; purging, 634–36; steady-state, 634
Airfoil fans, 615
Air-handling unit, 643, 644
Air-line respirator, 684–86; continuous flow, 686; demand, 685; pressure demand, 685-86
Air mixing, 646–47
Air movement: and cold stress, 13, 351; and exhaust ventilation hood, 608–11; for heat stress control, 347, 348; HVAC system problems with, 653; measurement of, 13, 336; natural ventilation, 632. See also Ventilation
Air-O-Cell cassette, 188, 200
Air pollution, 162–63
Air pressure (ventilation): calculation of, 624–25; and duct velocity, 626–27; static, 621, 622–24, 627–29; velocity, 625–27
Air-purifying respirator, 702
Air quality. See Air pollution; Indoor air quality
Air sampling, 27–28, 523–60; absorption, 525; active, 571; adsorption, 525–27; analysis, 195–202; area, 186–88, 523–27; for biological hazards, 457; vs. biological sampling, 142–43; direct-reading instrument for, 561-80; and exposure guidelines, 517; gases and vapors, 524–27; grab, 524; integrated, 524, 525–27; for ionizing radiation, 279; for lead, 144; for legionellae, 457; method, 532–36; for particulates, 186–94, 527–31.; passive, 527; personal, 523–24; record keeping for, 540–43; for respirator use, 668; sample collection device for, 524–32; for skin exposure monitoring, 73
Air-sampling suction pump, 531
Air speed, 337
Albinism, 53
Alcohol: and air pollution, 163; aliphatic, 131; breakthrough times, 681; chemical composition of, 161; for disinfection, 440; toxicological effects of, 28, 59, 131, 161
Aldehyde: and air pollution, 163; chemical composition of, 163; for disinfection, 440; toxicological effects of, 8
Algae. See Microorganism
Aliphatic hydrocarbon, 8, 131, 159, 164–65; biological effects of, 28, 159; breath analysis for, 144; and solvent hazard control, 165
Alkali: for disinfection, 440; hazard from, 28, 58, 131
Alkane, 152, 159, 163
Alkene, 159
Alkyne, 159
See also Sensitizer
Allergic alveolitis, 185
Allergic contact dermatitis. See Dermatitis, allergic contact
Allergy to Latex Education and Support Service (ALERT), 66
Alopecia, 68
Alpha-particles, 261–62
Alpha-particles, 261–62
Alpha-radiation, 14, 62, 258
Alveoli, 40–41, 47, 50
Amalgam, 570
Amar, contributions to ergonomics by, 358
Ambient water vapor pressure, 336–37
Ambulatory care facilities: infection control, 451
American Academy of Industrial Hygiene (AAIH), 739; and ethics, 4–5; graduate curricula, 735-36; membership qualifications in, 731
American Academy of Occupational Medicine, 766
American Academy of Ophthalmology and Otolaryngology (AAOO), 94, 101
American Association of Occupational Health Nurses (AAOHN), 776, 777, 778–81, 893
American Biological Safety Association, 444, 466, 467, 894
American Board for Occupational Health Nurses (ABOHN), 777
American Board of Health Physics, 762
American Board of Industrial Hygiene (ABIH), 728, 738–39, 894; certification of industrial hygiene professionals by, 510, 729–30, 731–32, 739, 746, 762; and ethics, 4–5
American Board of Preventive Medicine, 766
American College of Occupational and Environmental Medicine, 766–67, 879
American Conference of Governmental Industrial Hygienists (ACGIH), 138, 739–40, 894; Bioaerosol Committee, 458, 466; Biological Exposure Index (BEI), 139, 144, 202, 500, 502; committees, 466; Documentation of Threshold Limit Values, 141, 144, 159; and ethics, 4–5; Industrial Ventilation—A Manual of Recommended Practice, 608; membership in, 734, 740; and noise exposure measurement, 216, 240; particle size selection efficiency guidelines by, 529–30; Threshold Limit Values and Biological Exposure Indices, 13, 25, 69, 139, 489. See also Threshold Limit Value
American Cyanamid Co. v. OCAW, 848
American Dental Association, 863
American Federation of Government Employees, 859
American Industrial Hygiene Association (AIHA), 147, 458, 728, 738, 894; biological monitoring; Biosafety Committee, 466; An Ergonomics Guide to Carpal Tunnel Syndrome, 409; and ethics, 4–5; Hygienic Guide Series, 159; industrial hygiene defined by, 728; membership in, 734, 738; sampling laboratory accreditation by, 505; A Strategy for Assessing and Managing Occupational Exposures, 796
American Iron and Steel Institute, 826
American Iron and Steel Institute v. OSHA, 841, 879
American Journal of Infection Control, 424–25
American Medical Association (AMA): Evaluation of Permanent Impairment, 217; history of, 766; impairment guidelines of, 48–49, 97
American National Standard for Respiratory Protection, 668, 669, 695
American National Standard for Safe Use of Lasers, 309–12
American National Standard Method of Measuring and Recording Work Injury Experience, 831
American Optometric Association, 101
American Public Health Association (APHA), 767
American Petroleum Institute (API), 842
American Petroleum Institute v. OSHA, 840, 843
American Public Health Association, 424, 740–41, 894
American Smelting and Refining Company v. OSHRC, 834
American Society for Testing Materials (ASTM), 166, 194, 466, 571
American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), 466, 643, 894; Methods of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter, 649; thermal comfort standard of, 354, 648–49; ventilation standards of, 595, 647–48, 651
American Society of Microbiology (ASM), 420
American Society of Safety Engineers (ASSE), 148, 744, 749, 894
Americans with Disabilities Act (ADA), 734, 769, 789, 887
American Textile Manufacturers' Institute v. Donovan, 844
Ames test, 193
Amide, 153
Amine, 64, 153, 440
Ammonia, 130, 156, 158; direct-reading monitor for, 573; hazards from, 24, 47, 58, 129; reversibility of effect of, 129
Amosite, 180
Amplification, 86, 199
Amplifier, 219
Anaphylactic protein. See Allergen, biological
Anaphylaxis. See Sensitizer
Anemometer, 337
Anesthetic, 131, 162
Angioedema, 65
Anhydride, 28
Aniline, 68
Animal experimentation, 136–137, 141, 519
Animals, hazards from, 425–26, 433
Annihilation (electromagnetic), 258
Annoyance scale, 400
Annual audiogram, 238–39
Annual limit of intake (ALI) of radiation, 258–59
Annual Report on Carcinogens, 160
Anoxia, 23, 131
Antagonistic action, 141, 502, 504
Anthophyllite, 180, 856, 863
Anthrax, 188, 426, 427, 452
Anthropometric, 19, 370
Anthropometric Sourcebook, 369
Anthropometry, 19, 369–74
INDEX

Antimony, 58
Antineoplastics, 695
Antioxidant, 60
Aphakia, 304
Apocrine sweat, 53
Aqueous humor, 100, 101, 303
Aqueous solution, 150, 158, 166
Archaebacter, 421
Arachnid, 20, 420
Arbovirus, 423
Area monitoring (sampling), 499–500, 506–07, 523–24
Arine, 159
Argon ionization detector, 565
Armrests, for static work, 18–19
Armstrong, T. J., 409
Aromatic hydrocarbon, 8, 160, 165; biological effects of, 28, 57, 131, 160; breath analysis for, 144; photoionization detector for, 575; and solvent hazard control, 165
Arrectores pilorum, 54
Arsenic, 133, 172; biological sampling for, 203, 500; hazards from, 59, 60, 172, 186, 504; history of OSHA regulation of, 839, 844
Arthropod, 20
ASARCO v. OSHA, 844
Asbestos: area sampling for, 186, 528; cleaning and maintenance program for, 599; control methods for, 195–97; exposure monitoring of, 184; government regulation of, 196, 821, 829–30, 839, 856, 863, 877, 880; hazards from, 47, 132, 172, 178, 186; microvacuuming of, 194; sampling and analysis, 189, 195–98; varieties of, 180
Asbestos Hazard Emergency Response Act (AHERA), 197–98, 821, 874
Asbestos Information Association v. OSHA, 840, 856
Asbestos International Association, 196, 197
Asbestosis, 46, 47, 180, 184, 185, 186
As low as reasonably achievable (ALARA) concept, 267, 291
ASME Boiler and Pressure Vessel Codes, 590
Aspergillus, 200, 421, 463
Asphalt. See Petroleum products
Asphyxia, 23, 131, 159; chemical, 23, 23, 131, 159; simple, 131
Assigned protection factors (APFs), 693–94, 702
Associate Safety Professional (ASP), 746
Associated Industries v. Department of Labor, 838
Association of Professionals in Infection Control (APIC), 424–25, 466
Astatine, 160
Asthma, 46, 65, 459; atopic, 65
Asthmatic bronchitis, 129
Astigmatism, 104
Atelectasis, 47
Atlas Roofing Company Inc. v. OSHRC, 834
At least as effective as (ALAEA) state plan provision, 809, 830, 837
Atmosphere-supplying respirator, 702
Atmospheric pressure: and air sampling, 539; biological effects of, 16–17, 43
Atom, 178, 261, 281
Atomic number, 259
Atomic weight, 259
Atopy, 63
Attenuator, 219
Auchter, Thorne: deregulatory policies of, 845, 847, 851, 855, 860; emergency temporary standard for asbestos issued by, 856; OSHA assistant secretary term of, 851; and OSHA state plans, 853; response to OSHA criticism by, 852
Audiogram. See Audiometry
Audiometer, 93, 208, 234
Audiometry, 93–94, 208, 233–37; air conduction, 93; annual audiograms, 238; baseline audiograms, 238; bone-conduction, 93; specifications for, 234; testing, 235–36, 238; threshold, 234
Audit: of industrial hygiene program, 753, 800; safety inspection, 445, 753, 760
Auditory canal, 88–89
Auditory nerve, 87
Aural insert protector. See Earplug
Auricle, 83
Autoimmunodeficiency syndrome. See Human immunodeficiency virus
Automated information system. See Computerized industrial hygiene system
Autonomic nerve, 409
Autonomic nervous system, 359
Autophonia, 89
Auto Workers v. Johnson Controls, 135
Axial flow fan, 615, 638, 640

B

Bacillus anthracis, 178, 428, 452; subtilis, 178
Back belts, 387–88
Back school, 380
Background radiation, 259
Backward-curved blade fan, 615
Backward-inclined blade fan, 615
Bacteria: hazards from, 20, 62, 172; identification of, 420–21; natural defense against, 55; from particulates, 171, 199–201. See also Microorganism
Bagassosis, 185
Baghouse particulate air cleaner, 616
Balance. See Equilibrium
Barium, 59
Barotrauma, 16
Barrier cream, 75, 166
Basal ganglia, 361
Baseline audiogram, 238
Becherer, Antoine-Henri, 265
Becherer (Bq), 259
INDEX

BEIR V report, 267
Bel, 212
Bends, 16
Benzene, 8, 153, 681; and air pollution, 163; chemical composition of, 152; hazards from, 59, 160, 166; history of OSHA regulation of, 840, 842–43, 854, 865; substitutions for, 164. See also Aromatic hydrocarbon

Benzidene, 68
Benzoyl peroxide, 60
Berger's Manual of Determinative Bacteriology, 421
Beryllium, 133, 172, 178, 184, 193, 202
Beryllium Lymphocyte Proliferation Test (BLPT), 202
Beta-particles, 262–63
Beta-radiation, 14, 62, 259, 261
Bingham, Eula: OSHA policy of, 828, 831, 842, 843, 845, 846, 848, 850; OSHA standards advisory committee created by, 841; OSHA standards issued by, 843, 844, 848; and state plan benchmarks litigation, 837, 853; term as OSHA assistant secretary, 832, 842, 850; testimony at OSHA oversight hearing of, 849

Binocular vision, 101
Bioaerosol. See Aerosol, biological
Bioagent release; CDC emergency response, 453; decontamination, 454; identification of outbreak, 453; personal protective equipment, 454–55; response to, 454; role of professionals, 455
Bioassay. See Biological sampling
Bioelectromagnetics Society, 290
Biological agent, 452–53
Biological Defense Research Program (BDRP), 420
Biological exposure index (BEI), 25, 144, 202, 500, 502
Biological monitoring, 202
Biological organisms, 199–201
Biological safety. See Biosafety
Biological safety cabinet, 437–39
Biological sampling, 142–44, 186–88, 500–02; limitations of, 504–05

Biological toxin, 19; dermatosis from, 28, 57, 61
Biological warfare agents, 420
Biomechanics, 17–19, 374–78
Biosafety, 420, 440; guidelines for good large-scale practices, 478–84
Biosafety cabinet, 437–39
Biosafety equipment, 436–40
Biosafety in Microbiological and Biomedical Laboratories (BMBL), 431, 436, 448, 450
Biosafety in the Laboratory, 433, 444
Biosafety level (BSL), 430–33, 479–84
Biosafety manual, 443
Biosafety program, 442–45; support, 442

Biosafety specialist, 442–43
Biotechnology. See Recombinant DNA
Bioterrorism, 452–55; agents and treatments, 452; recognition of release, 453; release of biological agents, 452–53; response to release, 454–55

Birds. See Animals
Birth defect. See Teratogenesis

Bis (chloromethyl) ether (BCME), 133

Blastomogen. See Carcinogen
Blastomyces, 426
Bleach. See Chlorine; Sodium hypochlorite
Blindness. See Vision, impairment of

Blinking, 107, 303, 304
Blister, 61
Blood analysis, 49–50, 144, 500
Bloodborne pathogen, 445–55; controls for, 447–48, 790; history of OSHA regulation of, 860, 862, 881; standards for, 446, 447, 466, 790

Blood circulation, 329–30, 350
Blood disease, 133, 162. See also Anemia; Leukemia
Blood vessel, 54, 56, 408, 409

Board of Certified Safety Professionals (BCSP), 728, 746, 761
Body core temperature, 332, 333, 343
Body dimensions, 369–70
Bone, 262, 407
Bone-conduction hearing, 93, 230
Bone marrow, 265
Bony labyrinth, 87
Borelli, Giovanni Alfonso, 358, 374
Borg's rating of perceived exertion, 367
Botanical hazards, 62
Bovine spongiform encephalopathy (BSE), 424
Bronchial plexus neuritis, 409
Brain, 359, 361; damage, 161
Brake horsepower, 625
Braune, biomechanical research of, 374
Breath analysis, 144
Breathing, 41–46; rate, 45
Bremsstrahlung, 259, 263

Brennan, William, opinion in American Textile Manufacturers' Institute v. Donovan, 844
Brock, William E., 851, 857
Bromine, 59, 160
Bronchi, 39, 50
Bronchial constriction, 48
Bronchiole, 40, 46, 47, 48
Bronchioconstriction, 185
Bronchitis, 46, 47, 185
Bronchus, 39, 47
Brownian movement, 174, 182

Brucella, 423, 432
Brucellosis, 422, 423
Brying, 61
INDEX

Building-related illness (BRI), 20, 458–59; investigation of, 459
Bureau of Labor Standards, 237, 807
Bureau of Mines, 673, 693, 820
Burkhart Spore Trap, 188, 200
Burn, 69, 70; chemical, 69–70, 109, 158; classification, 69–70; complications, 70; from electric shock, 61; from electromagnetic radiation, 296, 304–05; to eye, 108; from hot environments, 349–50; incidence of, 56
Bursa, 408
Bursitis, 17, 399, 409
Bush, George, 875
Butadiene, 865, 878

C
Cadmium, 172, 191, 203, 500, 502, 865
Cadmium oxide, 48, 185
Calcium cyanide, 58
Calcium cyanamide, 58
Calcium oxide, 58
California Occupational Health Program, 505
Callus, 53, 61
Campus Safety Association, 466
Canopy hood, 611
Canal cap, 232
Cancer: from asbestos, 180, 183; from beryllium, 202; of bladder, 134; of bone, 132; bronchogenic, 47; from coal tar, 67; environmental factors in, 134; from ionizing radiation, 62, 266; of liver, 160; of lung, 132, 180, 184, 185, 186, 188, 502; occupational causes of, 133; from particulates, 47; of respiratory tract, 188; of skin, 55, 62, 68, 170, 304–05; subradiofrequency fields, 290–91; from sunlight and ultraviolet radiation, 55, 62, 68, 304. See also Carcinogen; Leukemia
Canons of Ethical Conduct, 4
Canopy hood, 611
Capsid, 421
Capture hood, 609
Carbofuran, 131
Carbolic acid. See Phenol
Carbon dioxide, 41–42, 45, 131, 163, 568, 651–53
Carbon disulfide, 8, 59, 68, 144, 504, 881
Carbon monoxide: diffusion capacity (D CO ), 49; hazards from, 24, 48, 131, 137, 158, 568; sampling for, 500, 568, 573; Threshold Limit Value for, 132
Carbon tetrachloride, 68, 160, 166, 681
Carboxyhemoglobin, 500
Carcinogen, 133–34, 141; administrative control methods for, 597; biological, 19; chemical, 7, 133, 134; history of OSHA regulation of, 838–39, 840, 843; safety guidelines for, 805–06. See also Cancer
Carcinoma. See Cancer
Cardiac sensitization, 131
Carlsson, B., 77, 78
Carpal tunnel syndrome, 17, 409–10, 411
Carter, Jimmy, 832, 842, 850
Cartilage, 407–08
Catalyst poisoning, 566
Catalytic combustible gas detector, 562
Cataract, 102, 105, 106, 296, 304
Cathode ray tube (CRT). See Video display terminal
Caustic. See Alkali
Ceiling limit, 25, 183; for heat stress, 338; OSHA determination of, 814, 839
Ceiling values, 140
Cement, burns from, 69
Center for Devices and Radiological Health (CDRH), 317
Center for Responsive Law, 852
Centers for Disease Control (CDC), 6; Bacterial and Mycotic Diseases Branch, 431; and biological hazard assessment and classification, 430, 452; biosafety guidelines, 431–34, 448, 449, 862–63; Biosafety in Microbiological and Biomedical Laboratories (BMBL), 431–33, 436, 448, 450; emergency response for biagent release, 453; guidelines for bioterrorism threats, 454; Hospital Infections Branch, 451; information resources, 149–50; legionellae contamination, 458; NIOSH organized under, 818
Central nervous system, 359, 361, 375
Central nervous system depressant (CNSD), 131, 159, 160, 161
Centrifugal fan, 615, 638
Centrifugation, and biosafety, 439–50
Cerebellum, 361
Cerebrum, 361
Certified associate industrial hygienist (CAIH), 732
Certified Safety Professional (CSP), 746
Cerumen. See Ear wax
Ceruminal gland, 84
Cervicobrachial disorder, 399, 409
Chamber of Commerce of the United States v. OSHA, 847
Checklist for hazard evaluation, 493–94, 495, 497
Chemical detector tubes: certification of, 572–73
Chemical hazard, 7–11, 21; burns from, 69–70, 109, 158; cataracts from, 109; control methods for, 80; dermatosis from, 57–61; evaluating, 124, 488; monitoring and control, 73–74; reactivity, 151; skin absorption, 690; solvents, 8–11; training on exposure, 756. See also Toxicity
Chemical Safety and Hazard Investigation Board, 874, 875
Chemical safety committee (CSC) and recombinant DNA, 443
Chemical Sampling Information CD-ROM, 532
Chemical Warfare Service, 420
INDEX

Chemisorption, 680
Chillblain, 351
Chimney effect, 639
Chlamydia, psittaci, 19, 426, 427
Chloracne, 66
Chlorinated ethylene, 163
Chlorinated hydrocarbon. See Halogenated hydrocarbon
Chloracne, 66
Chlorine, 130, 160; for disinfection of biological hazard, 441; hazards from, 28, 130
Chlorofluorocarbon (CFC), 131, 160
Choice reaction time, 362–63, 364
Choroid, 101, 304
Chromic acid, 28, 58, 201
Chromium, 59, 133, 172, 203, 866, 880
Chronic beryllium disease (CBD), 202
Chronic effect, 128
Chronic exposures, 128
Chronic obstructive pulmonary disease (COPD), 46
Chrysolite, 180
Chrysotile, 180, 196
Cigarette smoking: biological effects of, 46, 48, 106; OSHA standard proposed for, 865–66; second hand smoke, 186, 865–880; synergistic effects of, 132, 502, 504
Cilia, 37, 39, 48
Ciliary body, 100, 101
Circadian rhythm, 291
Circulating air system, 348
Circulating water system, 348–49
Circumaural protector. See Earmuff
Ciriello, V. M., 384-86
Classification of Etiologic Agents on the Basis of Hazard, 433
Clayton, F. E., 159, 162
Clayton, G. D., 159, 162
Clean Air Act Amendments, 162, 866, 874
Clean bench vs. biosafety cabinet, 439
Cleaning and maintenance, 30, 72, 73–74, 442, 448, 599; checklist, 494; and hazard evaluation, 488, 494; of respirator, 671–72; and workplace design, 589
Climatic conditions, 329; measurement of, 12–13
Clinical Laboratory Improvement Act (CLIA), 466
Clinical Toxicology of Commercial Products, 154
Clinton, Bill, 860, 875, 877, 887
Closed-cup flash point, 154
Closed-face filter cassette, 528
Clothing and thermal balance, 329, 347, 349, 350, 353
Coal dust, 24, 191, 427
Coal Mine Health Research Advisory Committee, 821
Coal tar, 59, 133, 160
Coast Guard, 835, 845
Cobalt, 172, 203
Coccioides, 421
Coccidioidomycosis, 188
Cochlea, 87, 94
Coconut shell charcoal, 525
Code of Ethics for the Practice of Industrial Hygiene, 4–5, 519
Coke oven emissions, 191, 838, 841, 861
Cold-related disorders, 351
Cold stress, 13–14, 329, 350–53; control methods for, 352–53; dermatitis from, 28; exposure guidelines, 351–52; measurement of, 351
Collection device. See Sample collection device
Color vision, 105
Colorimetric sampling device, 505, 570–74
Combustible gas, monitoring device for, 561–67
Combustible liquid, 157
Combustion systems, 617–18
Comfort scale, 400
Commissioning (of HVAC system), 644, 650
Commission Internationale d’Eclairage (CIE), 303
Commodity Specification for Air, 684
Communication (and hearing), 96–97; background noise, 96; clarity, 96; loudness, 96; medical evaluation, 97; quality of life, 96–97; rehabilitation, 97; speech sounds, 96. See also Hearing; Hearing loss; Noise
Complaints against state program’s administration (CASPA), 809, 837
Compliance safety and health officer, 732, 812, 813
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 822–23
Comprehensive practice examination, 762
Compressed gas, 154, 590, 672
Compressed Gas Association, 590
Compressed gas cylinders, 671–72
Compression: sound pressure, 212
Compton effect, 259
Computer workstation. See Office workstation; Video display terminal
Computer-aided design, 358
Concentration, 26–27, 151, 158, 159; and dilution ventilation, 633; lethal, 127; no-effect level, 126–27. See also Time-weighted average
Concentration–decay tracer gas calculation, 651–53
Conchae, 37
Condensation nuclei counters, 579–80
Condensed Chemical Dictionary, 154
Condutive hearing loss, 91
Conductive heat exchange rate, 328
Cones (of retina), 101, 105, 304
Confidence limit, 511
Confidentiality of health information, 783
Confined space, 868
Congenital malformation. See Teratogenesis
Conjunctiva, 100, 107, 109
Conjunctivitis, 65, 105–106
Connective tissue, 407–08
Constant air volume (CV) system, 644
Constant-concentration tracer gas calculation, 651–52
Constant-emission tracer gas calculation, 651–52
Construction Industry Noise Standard, 237
Construction industry regulation, 808, 826, 838, 856, 868, 871
Construction Safety Act, 826, 838; OSHA standards adopted from, 829
Construction Safety Amendments, 808
Construction Safety and Health Advisory Committee, 838
Consultation service, 31; by OSHA, 852, 876
Consumer Product Safety Commission, 850
Contact dermatitis. See Dermatitis, allergic contact; Dermatitis, irritant contact
Contact lenses, 106, 112–113
Containment: of biological hazards, 434–42; for tuberculosis control, 450. See also Enclosure; Isolation; Shielding
“Contract with America” Act, 877, 886–87
Contrast sensitivity (vision), 114
Control (of hazard), 29–30; appraisal during field survey, 496; of asbestos, 195–98; of biological hazards, 434–35; of cold stress, 352–53; of cumulative trauma disorders, 413–14; for eye safety, 113; of heat stress, 343–50; and industrial hygiene program, 797–98; of ionizing radiation, 274–79; of lasers, 111, 313–15; of noise, 226–33; of nonionizing radiation, 293, 302–03, 306–07, 313–15; of skin hazards, 73–74. See also Administrative control; Engineering control; Personal hygiene; Personal protective equipment
Controlled area, 259, 815
Control of Communicable Diseases Manual, 424
Controls (equipment), 19, 405
Convective heat exchange rate, 328
Coolant, 56, 60
Cooperative Compliance Program (CCP), 878, 882–83
Coordinated Framework for Biotechnology, 434
Copper, 108
Corn, Morton: OSHA policies of, 828, 832–33, 835; term as OSHA assistant secretary, 832
Cornea, 100, 101, 102, 106; foreign bodies in, 107–08; lacerations to, 107; optical radiation, 303
Corporate medical department, 767–68
Corrective eyewear, 102, 104, 113–14
Corrosives, 8, 131
Cortex, 361
Cost-effectiveness safety analysis, 761
Costoclavicular syndrome, 409
Cough, 38, 48, 185
Coulometric detector, 567, 569
Council for Accreditation in Occupational Hearing Conservation, 236
Counter, 259
Coupling and hand tools, 389–91
Coxiella burnetii, 423
Cranial nerves, 361
CRC Handbook of Chemistry and Physics, 152
Creosote. See Petroleum products
Cresol, 16
Cresylic acid, 58
Creutzfeldt–Jakob dementia, 421
Criteria document, 139, 157, 810, 819
Criteria Document on Hot Environments, 13, 325–26, 335, 337
Critical-flow orifice, 531–32
Criticality, 277
Crocidolite, 180, 196
Cross-sensitivity, 64
Crustacean, 20, 420
Cryogenic liquid, 154, 157
Cryptococcus, 421
Cryptosporidiosis, 423
Cubital tunnel syndrome, 399, 411
Cumulative trauma disorder, 17, 405–14; causes of, 406–07; countermeasures, 413–14
Curie (Ci), 259
Current Intelligence Bulletin (CIB), 139
Cutting oil, 56, 60, 62, 79
Cuyahoga Valley Ry. Co. v. United Transportation Union, 848
Cyanide gas, 24
Cyclic hydrocarbon, 159; and solvent hazard control, 165; toxicological effects of, 159
Cycloalkane, 159
Cyclohexane, 153
Cyclone: for particulate sampling, 529; for air cleaning, 616
Cytochrome oxidase system, 131
Cytomegalovirus (CMV), 429

D
Damage control program, 760
Damage-risk criteria, 216–17
Damper, 644, 647
De Morbis Artificum, 765–66
Dead finger. See Raynaud’s phenomenon
Deafness. See Hearing loss
Dear, Joseph, 860, 869, 870, 878
Decay (radioactive), 264
Decibel, 212–15
Decompression sickness, 16, 158
Decontamination, 440; of biological agent exposure, 454
Dehydration, 331, 333, 352–55
Demand respirator, 702
Density, 285
Department of Agriculture, 434, 466; Food Safety and Inspection Service, 875; Food Safety and Quality Service, 850
Department of Commerce, 434, 466
Department of Energy, 193
Department of Health and Human Services, 237, 808; Healthy People 2010, 786; mine health advisory committee appointed by, 820; NIOSH established by, 808; Registry of Toxic Effects of Chemical Substances, 138
Department of Labor, 139, 216, 807, 808, 810; mine safety enforcement by, 820–821; NIOSH recommended stan-
INDEX
Ear: anatomy of, 83–88; atmospheric pressure effects on, 16, 89; hearing measurement, 93–94; hearing process, 92; noise exposure, 94–95; pathology of, 87–92 physiology of, 83–88
Ear canal, 88–89; and earplug fitting, 231–32; cap for hearing protection, 232
Eardrum: anatomy of, 85; pathology of, 89; physiology of, 85, 89; and sound, 208
Earmuff, 229–30, 232, 233
Earplug, 229–30; 231–32, 233
Ear wax, 89; and earplug fitting, 231–32
Ebola, 423, 426
Eccrine sweat, 54
Echinococcosis, 426
E. coli, 425
Eczema, atopic, 63
Education for Latex Allergy Support Team and Information Coalition (ELASTIC), 66
Education and Resource Center (ERC), 7, 735, 819
Effective temperature, 12, 337; corrected, 337
Effector, 362
Ekman's rating of perceived exertion, 367
Elastic waves, 210
Electret fibers, 676
Electric field, 281–82; biological effects of, 287–89; control of, 293; direct current (DC), 288–89; exposure guidelines for, 289-90; measurement of, 287, 291-92; microwave, 293–94; pulsed, 297–98; vs. radiation, 285, 287; radiofrequency, 293–94; strength, 287; subradiofrequency, 287-88; time-varying, 290–91; types of, 285; in video display terminal, 301. See also Nonionizing radiation
Electric Power Research Institute, 292, 341
Electrical hazard, 61, 296; federal regulation of, 858, 868
Electrocardiogram (ECG), 289-90
Electromagnetic device, 287
Electromagnetic radiation, 283–85, 302; and interaction with matter, 302; spectrum, 285. See also Ionizing radiation; Nonionizing radiation
Electromyography (EMG), 376
Electron, 259, 261, 281
Electrostatic attraction (particles), 174, 675–76
Electrostatic precipitator, 529–30, 616
Element, 259
ELF radiation. See Extremely low frequency radiation
Elutriator, 530–31
Emergency care: for eyes, 109; OSHA evaluation of, 815–16; TB skin testing, 451; for temperature-related disorders, 345–46
Emergency situation, 702
Emphysema, 47, 48, 185
Employee and heat stress behaviors, 330–31; injury and illness record, 755; medical removal protection (MRP), 845; participation under OSHAct, 808, 827, 831, 847–48; role in occupational health, 6, 78, 800, 802; safety education and training, 756–59; walkaround right, 831, 847; whistle-blower protection, 831, 874, 885
Employee assistance program (EAP), 787
Employee exposure, 702
Employee health care program. See Occupational health program
Employer, responsibilities under OSHAct, 808, 826
Employment Standards Administration, 876
Enclosure, 30, 165, 594; for exhaust ventilation hood, 609–11; hearing protective, 230–31; for laser control, 313–15; for noise control, 230–31; for plutonium control, 278. See also Containment; Isolation; Shielding
End-of-service-life indicator (ESLI), 702
Endotoxin, 188, 200–01, 421, 427, 461–62; concentrations, 462; health effects, 461–62; RLV, 462; sampling, 462
Energy dispersive x-ray fluorescence, 197
Engineering control, 29, 165, 586; of cold stress, 353; of cumulative trauma disorders, 413; at design stage, 587–91; of heat stress, 346; of lasers, 313–15; of noise, 227–29; of organic dusts, 463; OSHA requirements for, 586, 817, 839, 879; principles of, 591–97; of radioactive particulates, 198; of skin hazards, 73; of solvents, 29, 165
Engineering program, 751
Environmental control. See Engineering control
Environmental Protection Agency (EPA), 821–22; asbestos regulation by, 197, 198, 821; and biological hazards, 434, 466; and Comprehensive Environmental Response, Compensation and Liability Act, 822–23; emission requirements, 493; Hazardous Chemical Reporting Rules, 822–23; lead regulation by, 821; National Primary Ambient-Air Quality Standards, 648; noise regulation by, 216, 233; and OSHA jurisdiction, 838, 850, 875; radon regulation by, 821; and Resource Conservation and Recovery Act, 600, 821–22; and Toxic Substances Control Act, 138, 821
Environmental stresses, 7–20
Epicondylitis, 409, 411
Epidemiology, 138–139, 488
Epidermis, 52–53, 55
Epiglottis, 38
Epinephrine, 131
Epoxy, 162
Equal-loudness contour, 215
Equilibrium, 87; impairment of, 92; and vapor pressure, 150
Equipment: checklist, 494; design of, 19, 436–40, 751; purchasing of, 751–52
Equivalent aerodynamic diameter (EAD), 180
Equivalent chill temperature (ECT), 351
Ergonomic hazard, 7, 17–19; OSHA regulation of, 860, 868, 871, 878
Ergonomics, 17, 357; and anthropometry, 369–74; and biomechanics, 17–19, 374–78; and cumulative trauma disorders, 405–14; and equipment design, 436–40; evaluation of, 790; and hand tools, 388–391; and material handling, 378–82; and workplace design, 382–88, 392–95; and workstation design, 392, 395–404

An Ergonomics Guide to Carpal Tunnel Syndrome, 409

Erysipelas, 426

Erysipelothrix rhusiopathiae, 427

Erythema. See Sunburn

Escape-only respirator, 702

Escherichia coli, 421

Esophagus, 37, 38, 39

Ester: biological effects of, 28, 161–62; breath analysis for, 144; chemical composition of, 153, 161–62

Ethane, 131

Ethanol, 159, 161

Ether: biological effects of, 28, 162; breath analysis for, 144; chemical composition of, 153, 162

Ethics, 4-5

Ethylene glycol ethers, 68, 201

Ethylene oxide: for disinfection, 440, 441; federal regulation of, 840, 854, 858, 863

Ethyl ether, 162

Eubacteria, 421

Eukaryote, 421

European Commission for Electrotechnical Standardization (CENELEC), 581

European Federation of Biotechnology, 431

Eustachian tube, 37, 85, 16, 89; pathology of, 89

Evaluation (of hazard), 7, 26–28, 487–521; checklists, 493–94; field survey for, 495–97; and industrial hygiene program, 795–97; interview for, 488; by process analysis, 495; purpose of, 488; and Toxic Substances List, 138. See also Monitoring; Sampling

Evaluation of Permanent Impairment, 217

Evaporative heat loss, 329; by respiration, 329

Excimer lasers, 316–17

Exhaust ventilation, 30, 595–97, 607–29, 631; air cleaner, 608, 615–18; airflow principles, 618–20; design of, 596–97; dilution, 30; duct, 608, 611–12; fan, 608, 615; general, 30; hood, 596, 608–11; makeup air, 618; for solvent hazard control, 165; system performance, 625–29

Exogenous infection, 422

Exhaust stacks, 612–15

Expiratory reserve volume (ERV), 45

Explosives, 8, 60

Explosive range, 157, 562

Exposure: acute, 128; chronic, 128; and mode of use, 151–52; and vapor pressure, 151

Exposure assessment: of respirator wearers, 668

Exposure guidelines, 30; for airborne contaminants, 23–24, 138–39, 151–52, 183–84; for biological hazards, 430–33, 465–66; for cold stress, 351–52; for cumulative trauma, 413; for heat stress, 13; for ionizing radiation, 271; for noise, 11; for nonionizing radiation, 389–91, 295–99, 303–07; and sampling results, 516–19. See also Permissible Exposure Limit; Recommended Exposure Limit; Threshold Limit Value

External auditory canal, 83–85

External ear, 83–85, 88–89; pathology of, 88–89

External work rate, 328

Exteroceptor, 361

Extremely low frequency (ELF) radiation, 287; biological effects of, 287–91; field strength, 287; magnetic field measurement, 292

Eye: anatomy of, 99–101; burn of, 108, 109; chemical hazards to, 59, 108–09; defects, 102–04; disorders, 105–07; emergency care for, 109; evaluation, 114–15; infection, 107–08; inflammation, 59, 266; ionizing radiation effects on, 266; nature of defenses of, 303–04; nonionizing radiation effects on, 16, 108; optical radiation exposure, 303–04; physical hazards to, 107–09; problems, 104–04; protective equipment, 110–13; and radiofrequency and microwave exposure guidelines, 296, 300–01; vision conservation program, 113–14; visual performance, 104–05. See also Corrective eyewear; Protective eyewear; Vision Eyeglasses. See Corrective eyewear

Eye-hazard area concept vs. job approach, 109

Eyestrain, 106, 399

Eyewash fountain, 109, 598

F

Factory Mutual Engineering Corp., 531

Failure mode and effects analysis (FMEA), 495, 761

Fair Labor Standards Act, 831, 875, 887

Fan, 608, 615, 638, 640; axial-flow, 615, 638; centrifugal, 615, 638; for HVAC system, 644; noise from, 638; static pressure, 624. See also Dilution ventilation; Ventilation

Fan laws, 624–25

Faraday cage, 303

Farmworker Justice Fund Inc. v. Brock, 857, 858

Farm Workers Occupational Safety and Health Oversight Hearings, 835

Farnsworth D15 Panel Test (vision), 105

Farsightedness, 102–03

Fascia, 408

Fascia, 408

Fatigue, 368–69

Fault tree analysis, 495, 761

Federal Agency Safety Programs, 841, 849

Federal Aviation Administration, 850

Federal Bureau of Investigation (FBI), 454

Federal Coal Mine Health and Safety Act, 819, 820, 821, 826

Federal Emergency Management Agency (FEMA), 454

Federal Employee Health and Safety Program, 832, 841–42, 850, 859

Federal Facility Compliance Act, 822

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), 138, 838

INDEX
INDEX

Federal Metal and Nonmetallic Mine Safety Act, 820
Federal Mine Safety and Health Act, 807, 820, 835
Federal Mine Safety and Health Review Commission, 820
Federal Radiation Council, 267
Federal Railroad Administration, 835
Federal regulations, 6–7; for asbestos exposure, 196-98; for biological hazards, 465-66; and exposure guidelines, 25–26, 138–39; for eye and face protection, 109–10; for insecticides, 138; for laser exposure, 314–15; for noise exposure, 225–26, 237–38, 242–55; before OSHAct, 769; for radiofrequency and microwave exposure, 301; safety professional’s familiarity with, 749; and sampling results, 517. See also specific regulations
Ferric chloride, 28
Fertility. See Reproductive hazard
Fetal protection policy, 861
Fiber, 180; monitors, 580
Fibrosis, 47, 185
Field blank, 536
Field Inspection Reference Manual (FIRM), 733
Field Operations Manual, 733
Field sanitation, 854, 857, 858
Field survey, 495–97
Film badge, 15, 259, 268
Filovirus, 426, 433
Filter: for aerosol-removing respirator, 675–79; for air cleaner, 616; for air disinfection, 450; for asbestos, 196; for biosafety cabinets, 437–38; diffusion, 675; electret fiber, 676; electrostatic capture, 675–76; high-efficiency particulate air (HEPA), 684, 698; for HVAC system, 644; interception capture, 675; for measuring particulate exposure, 189; NIOSH–MSHA certification of, 677–79; for particulates, 527–28; for power air-purifying respirator, 683–84; for respirator, 450, 702; sedimentation capture, 675; for tuberculosis control, 450
Fire fighter, respirator for, 692–93
Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids, 154
Fire point, 157
Fire safety, 315, 633, 637
Firestone Plastics Co. v. Department of Labor, 840
First aid. See Emergency care
First-aid report, 755
First-degree burns, 69
Fischer, biomechanical research of, 374
Fit factor, 702
Fit testing, for respirator, 696–701, 702, 706, 711-21; qualitative, 696-98; quantitative, 698–99
Fitts’ Law, 363
Flame ionization detector, 575
Flame photometric detector, 578
Flammable and Combustible Liquids Code, 154
Flammable liquid, 8, 154, 157
Flammable materials and lasers, 314
Flammable range. See Explosive range
Flanged hood, 609
Flash point, 154
Fletcher–Munson contour, 215
Florida Peach Growers Association v. Department of Labor, 838, 840
Flow-rate meter, 531-32, 571
Fluid replacement, 344
Fluorescent tube, 321–22
Fluoride, 60, 203
Fluorimetric affinity biosensor, 574–75
Fluorinated hydrocarbon. See Halogenated hydrocarbon
Fluorine, 160
Fluorocarbon, 163
Folliculitis, 28
Fornix, 359
Foreign bodies, in eye, 107–08
Formaldehyde: biological effects of, 28, 60, 130; for disinfection, 440, 441; monitor for, 570; OSHA regulation of, 840, 864; Threshold Limit Value for, 570
Formic acid, 58
Forsberg, K., 78
Fort Detrick Biological Defense Research Program (BDRP), 420
Forward-curved blade fan, 615
Foulke, Edwin G., Jr., 875
Fourier-transform infrared (FTIR), spectrophotometer, 576–77
Fovea, 104, 304
Free crystalline silica, 195
Freestanding occupational health clinic, 768
Freon, 160
Freon TF, 160
Frequency, 210–11
Friction, 28, 61, 611
Fritted bubbler, 525
Frostbite, 13–14, 61-62,88, 351
Frostnip, 351
Fume, 22, 48, 171; air cleaner for, 618; respirators for, 675–79; from welding, 22
Functional residual capacity (FRC), 46
Functional Vision Score (FVS), 114
Fungus: biological effects of, 19, 24, 28, 47, 62, 427; concentrations of, 464; endotoxic, 460; identification of, 420–21; mycotoxic, 464; from particulates, 24, 171, 199–201. See also Microorganism
Fusarium, 200, 464
Gamma-radiation, 14, 254, 261, 263–64; dermatosis from, 62; shielding for, 272–73

Gas, 22, 524; absorption of, 22, 617; adsorption of, 617, 680; asphyxiant, 156; biological effects of, 8, 23–24, 47–48, 108–109, 129; concentration calculation, 151, 512–13; control methods for, 158; inhalation of, 124–25; irritant, 8, 48, 129; in lasers, 316–17; mode of use and exposure hazard, 151; properties of, 150; sampling devices for, 524–27; toxic, 23, 48, 154, 316–17

Gas chromatograph, 201, 578

General Industry Noise Standard, 237

Gerarde, H. W., 159, 160

Giardia, 421, 427

Glare, 319, 399

Glass fiber filters, 527

Glasses. See Corrective eyewear; Protective eyewear

Glaucoma, 102, 105, 106

Gleason, M. N., 154

Global warming, 163

Globe temperature, 13, 337

Glove box, 278

Gloves, 77–78, 603; vs. barrier cream, 75; latex, 66; permeability of, 166; selection, 78; for solvents, 166

Glutaraldehyde, 440, 441, 573, 881

Glycerol, 161

Glycol, 153, 161, 162

Goggles, 110, 167, 315

Golgi organ, 361

Gonioscope, 102

Good large-scale practices (GLSP), 432, 478–84

Goose bumps, 54

Government regulations. See Federal regulations; State and local regulations

Grab sampling, 505, 524

Grain dust, 191

Grain handling, 859, 867

Grandjean, E., 398, 402

Granuloma, 68

Graphite, 191

Graphite furnace atomic absorption spectrophotometer, 195

Gravimetric analysis, 198–99

Gray, Wayne B., 877

Gray (Gy), 259

Greenhouse effect, 163

Gross alpha, beta, gamma analysis, 198

Ground fault circuit interrupters (GFCIs), 838

Guenther, George C., 827, 831, 832, 835

Guides to the Evaluation of Permanent Impairment, 70, 71; of hearing, 217; of respiration, 48–50; of skin, 71–72; of vision, 114-119

Guyon tunnel syndrome, 413

Hair, 54; loss from ionizing radiation, 266

Hair follicle, 54, 55

Half-life, 259, 263, 264

Half-value layer, 259, 263

Hall effect, 292

Halogen, 160, 440

Halogenated hydrocarbon, 8, 131, 152, 160–161, 165; and air pollution, 162–63; biological effects of, 28, 160; breath analysis for, 144; and solvent hazard control, 164–65

Halogen-containing compound, 68

Hamann, C. P., 78

Hand, 17–18

Handle, 388, 390

Hand tool, 388–91

Hand washing rinsate analysis, 194

Hantavirus, 423, 426

Hantavirus pulmonary syndrome, 426

Hardware. See Computerized industrial hygiene system

Harless, biomechanical research of, 374

Hay fever: atopic, 63

Hazard, 7–20, 27; classification, 430–34; control of, 164–67, 586; degree of, 27; elimination, 759; evaluation, 139, 163; identification, 759; medical surveillance, 502; protection, 759–60; and recognition of, 26–27; 488, 795–97; of respiration, 46–48; vs. toxicity, 11, 124

Hazard and operability study (HAZOP), 495

Hazard communication program, 811-12

Hazard Communication Standard, 7, 138, 144, 811–12; history of, 848, 855–56; and Paperwork Reduction Act, 860–61, 864; training program required by, 815

Hazardous waste management, 600; federal regulation of, 600, 810, 821–22, 861, 867

Health care facility: biological hazards in, 424–25, 449; regulation of, 450; respirators for use in, 695. See also Employee health care facility

Health Effects Research Laboratory, 581

Health Hazard Evaluation (HHE), 7, 519, 819

Health physicist, certified, 762

Health Physics and Radiological Handbooks, 290

Health Physics Society, 258, 894

Health Research Group, 880

Health surveillance program, 605

Healthy People 2010: National Health Promotion and Disease Prevention Objectives, 786
Hearing, 83, 92, 208; and communication, 96–97; measurement of, 93–94, 97, 211, 212–15, 216, 217, 234, 236; protection, 229–30, 603; speech, 217; standard threshold shift (STS), 238–39; threshold of, 94, 217, 234; and threshold of pain, 212

Hearing aid, 97

Hearing Conservation Amendment (HCA), 97, 237, 239, 242–55; history of, 839, 855

Hearing conservation program, 97–98, 223, 237–40; record keeping for, 236–37, 240, 246–47

Hearing loss, 96–97, 208; causes of, 94; and chemical hazard synergism, 504; communication problems from, 96–97; conductive, 91, 94–95; measurement of, 93–94, 97, 210, 217, 234, 238, 243–45; noise-induced, 94–95; risk factors for, 217–18; sensorineural, 92, 97; and tinnitus, 92; treatment for, 97

Hearing-protective device, 229–30, 230–33, 239

Heart rate, 330, 332–33, 343, 365

Heat balance analysis, 335, 339–40, 341–42

Heat cramps, 12, 61, 331

Heat exhaustion, 12, 61, 331

Heat loss, 13, 351

Heat rash, 61, 67, 331

Heat-related disorders, 331–32

Heat storage rate, 328


Heat Stress Index (HSI), 13, 342

Heat stroke, 12, 61, 331

Heat syncope, 331

Helium, 131, 154

Helmet: hearing-protective, 231; respiratory, 702

Hemoglobin, 42

Henry, N., 77

HEPA filter. See High-efficiency particulate air (HEPA) filter

Hepatitis, 422, 500; A virus, 20, 427; B virus (HBV), 125, 420, 423, 429, 432, 446; B virus, history of OSHA regulation of, 446, 860, 869, 881; B virus, vaccination program, 790; C virus (HCV), 20, 125, 423, 446–47; C virus, history of OSHA regulation of, 881

Herpes simplex, 106, 429

Herpes virus: simiae (B), 426

Hertz, Heinrich, 283

Hertz (Hz), 210, 283

Hexane, 150

Hiccup, 38

High-efficiency particulate air (HEPA) filter, 175, 702; for air disinfection, 451; for biosafety cabinets, 437; for handling plutonium, 278; isokinetic sampling, 192–93; for particulates, 175; for respirator, 450, 684, 698; for tuberculosis control, 450, 451; for vacuum, 494

High Risk Occupational Disease Notification and Prevention Act, 874

Hindbrain, 359

Histoplasma, 427

Histoplasmosis, 421, 426

HIV. See Human immunodeficiency virus

Hive. See Urticaria

Holding. See Coupling; Handle

Home office design, 404

Hood, 608–11, 702; static pressure, 622–24, 627–29; types, 608–11

Hood entry loss, 622

Hood entry loss coefficient (F), 622

Horny layer. See Stratum corneum

Hospital. See Health care facility

Host susceptibility, 428–29

Housekeeping. See Cleaning and maintenance

Housing and Community Development Act, 864, 874

Housing and Urban Development (HUD): surface sampling, 193, 194

Human Factors and Ergonomics Society, 357, 894

Human immunodeficiency virus (HIV), 125, 423, 426, 428; exposure guidelines for, 000; history of, 447, 826, 860, 869, 881

Human subject review board (IRB), 443

Humidity, 63; HVAC system problems with, 653; measurement of, 12, 336–37, 650, 651; reduction of, 346–47; relative, 681–82

HVAC system, 587, 631, 644; and indoor air quality problems, 647; and legionnaires’ disease, 456; maintenance, 653–54; standards, 647–50, 866; troubleshooting, 653; zones, 644–47

Hybridoma technology. See Recombinant DNA

Hydrazine, 881

Hydrocarbon, 152; and air pollution, 162–63; oxygen-containing, 153

Hydrochloric acid, 24, 58

Hydrochlorofluorocarbon (HCFC), 160, 591

Hydrofluoric acid, 24, 47, 151

Hydrogen, 131

Hydrogen cyanide, 132, 150

Hydrogen fluoride, 24, 47, 151

Hydrogen halides, 150, 158

Hydrogen peroxide, 28, 60, 441

Hydrogen sulfide, 131, 132, 150, 524

Hygienic Guide Series, 159

Hygrosopic agent, 28

Hyperabduction syndrome, 412

Hyperbaric environment. See Atmospheric pressure

Hyperhidrosis, 62

Hyperopia, 102-03

Hypertension, 67, 68

Hypersusceptibility, 129

Hypochlorite, 28

Hypopigmentation, 67
Hypothermia, 13, 350, 352, 351
Hypoxia, 131
IBP Inc. vs. Secretary, 885
Ice garment, 349
Illumination. See Lighting IES, Illumination Engineering Society (IES), 15, 317, 894
Immediately dangerous to life or health (IDLH), 692, 702
Immunization, 444, 448, 786
Impact, 675
Impactor, 530
Impact-resistant eyewear. See Protective eyewear Impinger, 525, 530
In-vitro testing, 136
Incus, 85, 86
Index of Difficulty, 363
Indoor air quality, 643; calculation of, 651; monitor for, 568; standards, 865–66, 880
Indoor Radon Abatement Act, 821
Inductively coupled plasma atomic emission spectrometer (ICPAES), 195
Inductively coupled plasma-mass spectrometer (ICP/MS), 195
Industrial hygiene, 3–4; code of ethics, 4, 5; control methods, 591
Industrial hygiene manager, 731
Industrial hygiene program, 3–4, 667, 794; and employee involvement, 800, 802; and employee training, 798–800; evaluation of, 800; and hazard evaluation and control, 795–98; implementation of, 793, 794; organizational responsibilities, 800–02; and record keeping, 800; summary of criteria and activities, 795; written, 794–95
Industrial hygienist, 3–4, 144, 727–41; and biosafety, 466–67; certified (CIH), 510, 731–32, 762; civil service, 732–34; education and training of, 730–32; functions of, 730–31; job descriptions, 728–32; skin protection, 78
Industrial hygienist-in-training (IHIT), 729–30
Industrial Truck Association v. Henry, 888
Industrial Union Department v. American Petroleum Institute, 843
Industrial Union Department v. Bingham, 843
Industrial Union Department v. Hodgson, 830
Industrial Ventilation—A Manual of Recommended Practice, 165
Inertial impactors, 173–74, 530
Infection, 19, 28, 421–22, 424–26; control, 447–48, 451; of ear, 88, 89, 90; epidemiology of, 422–23; of eye, 105–06; modes of transmission, 427–28; and particulate inhalation, 185; and reproductive hazards, 429; secondary, 61, 62
Infection Control and Hospital Epidemiology, 425
Infectious dose, 425, 428
Infectious waste, 440, 442
Inflammation: of eye, 59, 105–06, 266; of soft tissue, 408
Influenza vaccine, 431
Information processing, human, 359–63
Information system. See Computerized industrial hygiene system
Infrared analyzer, 576
Ingestion, 21, 125; of biological agent, 422, 428
Inhalation, 21, 124–25; of biological aerosols, 422, 429–30; and hazard control, 140, 415; of ionizing radiation, 279; of particulates, 170
Injection: of biological hazard, 428; of toxin, 125
Inner ear: anatomy of, 87; cochlea, 87; pathology of, 91-92; physiology of, 87; vestibular system, 87
Inoculation. See Injection; Immunization Insect, 20, 420
Insecticide. See Pesticide Inspiratory capacity (IC), 66
Inspiratory reserve volume (IRV), 45
Institute of Electrical and Electronic Engineers (IEEE), 297, 298
Institute of Occupational Medicine, 192, 454
Institutional animal care and use committee (IACUC), 443
Institutional biosafety committee (IBC), 442, 443
Instrument Society of America (ISA), 581
Insulation, 329
Intake (for HVAC system), 644
Integrated Management Information Systems (IMIS), 733
Integrated Risk Information System (IRIS), 519
Integrated sampling: absorption, 525; adsorption, 525-27; vs. grab sampling, 524
Interagency National Response Team, 875
Interagency Regulatory Liaison Group (IRLG), 850
Interception (particle deposit), 174, 675
Interior structural firefighting, 702
International Agency for Research on Cancer (IARC), 160
International Atomic Energy Agency (IAEA), 276
International Commission for Non-Ionizing Radiation Protection (ICNIRP), 289, 290
International Commission for Radiological Protection and Measurements (ICRP), 259, 267
International Conference on Radiation Protection, 183
International Electrotechnical Commission (IEC), 581
International Lighting Commission (CIE), 303
International Organization for Standardization (ISO), 190, 336, 338, 342, 735, 794
International Union of Pure and Applied Chemistry, 152
Interreceptor, 361
Intersociety Committee on Guidelines for Noise Exposure Control, 217-18
Intertrigo, 67
Interview, for hazard evaluation, 496–97
Intrapulmonic pressure, 44
INDEX

Introduction of Recombinant DNA-Engineered Organisms into the Environment, 433
Inventory, of chemicals, 489
Investigation, accident, 753–54
Iodine, 28, 160
Iodophor, 440, 441
Ion, 259, 282, 575
Ionization chamber, 260, 269
Ionizing radiation, 257–80, 259; biological effects from, 62, 14–15, 28, 62, 67, 106, 133, 264–67; and chemical exposure, 141; control methods for, 274–79; electromagnetic spectrum, 285; exposure factors, 271; monitoring exposure to, 195, 268–70; exposure standards for, 271, 267–70; external hazard from, 14, 279; internal hazard from, 14, 279; latent period, 266; measurement of, 14–15, 268; nuclear, 261; operational safety factors, 271–74, 278; record keeping for, 279; safety factors, 14; shielding from, 263; sources of, 275–77; types of, 261–64
Ion mobility spectrometer, 579
Ion pair, 261
Iris, 101, 303
Iritis, 109
Irradiance, 285
Irritant, 7–8, 129, 158, 159; of respiratory system, 129; vs. sensitizer, 64; strong vs. weak, 64. See also Dermatitis, irritant contact
Irritant fume protocol, 698
Irritant contact dermatitis. See Dermatitis, irritant contact
Ishihara color plate test (vision), 105
ISO. See International Organization for Standardization
Isoamyl acetate protocol, 697
Isocyanate, 60, 151, 172, 192
Isokinematic technique, for material-handling personnel selection, 376
Isokinetic sampling, 192–93
Isolation, 30, 279, 586, 592–95. See also Containment; Enclosure; Shielding
Isomer, 152
Isometric work, 18–19
Isotope, 260
Isotopic enantiomer, 179
Itching, 72

K
Kaolin dust, 191
Kepone incident, 831, 833
Keratin, 54
Keratin layer. See Stratum corneum
Keratinocyte, 52, 304
Keratin solvent, 57
Keratin stimulant, 57
Keratitis, 59, 108, 295
Keratoacanthoma, 68
Keratoconjunctivitis, 108
Keratosis, 59, 68
Ketone, 153, 161; and air pollution, 163; aliphatic, 131; breath analysis for, 144; for disinfection, 440; toxicological effects of, 8, 28, 161
Keyboard user, cumulative trauma disorders of, 406
Kick, S. A., 78
Kidney damage, 162
Kinetic Limulus Assay with Resistant-Parallel-Line Estimation (KLARE), 201
Kirkland, Lane, 829, 850
Konimeter, 202
Korean hemorrhagic fever, 423, 426
Kuru, 421
Kyphosis, 397

L
Label (for controls and displays), 405
Laboratory: biological hazards in, 424; design of, 435–36; history of OSHA regulation of, 864; tuberculosis controls for, 451–52
Laboratory animal allergy (LAA), 425
Labyrinthitis, 92
Laceration, 56, 61; to eye, 107
Lacrimal gland, 100, 107
Lacrimation, 108, 109
Lactic acid, 58
L'Ambiance Plaza construction accident, 868, 871
Langerhans' cells, 53
Laryngitis, 39, 46
Larynx, 38–39, 50
Laser, 307–17; biological effects of, 16, 304, 308–09; and blinking, 304; continuous wave (CW), 308; controls for, 111, 313–15; dermatosis from, 62; exposure guidelines for, 308; eye protection, 111; nonbeam hazards of, 315–17; pointers, 315; pulsed, 308, 312
Laser Institute of America (LIA), 309, 310–12, 317
Laser Institute of America (LIA), 309, 310–12, 317
Lawrence Livermore National Laboratory, 314, 316
Lead, 172, 184; biological effects of, 131, 132–133, 137; biological monitoring of, 203; biological sampling for, 500, 501; blood analysis for, 143, 144; cleaning and maintenance program for, 599; federal regulation of, 502, 821, 839, 840, 844, 861, 863–64, 874, 877, 879; surface sampling, 193

J
Jefress, Charles N., 878
Jamar dynamometer grip strength testing, 772
Job design, 378
Job safety and health analysis, 753, 756, 759
Johansson, contributions to ergonomics by, 358
Joint Commission on Accreditation of Healthcare Organizations (JCAHO), 424, 466
Journal of Occupational and Environmental Medicine, 767
Justice National Crime Victims Survey, 882
Lead Industries Association (LIA), 845
Leather. See Animals
Legionella, 188, 455; pneumophila, 20, 427; sources of, 456
Legionellosis, 455–58; prevention of, 457–58
Legionnaires’ disease, 188, 430, 455; transmission of, 456, 459
Length-of-stain dosimeter, 571
Lens (of eye), 100, 101, 102; injury to, 106. See also Aphakia
Leone v. Mobil Oil Corp., 831
Leptospira interrogans, 427
Lethal concentration (LC), 127
Lethal dose (LD), 127
Leukemia, 133, 134
Leukoderma, 67
Lichen planus, 63
Lifting. See Material handling
Lifting index (LI), 384
Ligament, 408
Lighting, 15, 317–22; colored, 321, 405; of computer office, 399; and contrast, 319; excessive, 106; fluorescent tubes, 321–32; and glare, 319, 399; for video display terminal use, 319, 322
Light signal, colors for, 405
Limitation of Exposure to Ionizing Radiation, 279
Limit of detection (LOD), 532
Limulus amebocyte lysate (LAL) test, 201, 462
Lind, Alexander, 338
Lipid-soluble material, 52, 57
Lipopolysaccharides, 461, 462
Liquid scintillation counting, 198
Literature review, and hazard evaluation, 488–89
Liver damage, 161
Load constant (LC), 383
Load handling. See Material handling
Loading operation, 590
Local exhaust ventilation. See Exhaust ventilation
Lockout/tagout (LOTO), 866–67
Log-normal distribution, 176–77
Longshoremen and Harbor Workers Act, 827, 829, 881
Loops (magnetic measurement), 292
Loose-fitting facepiece, 702
Lordosis, lumbar, 397
Loss retention, 760
Loudness, 215–16
Louisiana Chemical Association v. Bingham, 848
Lower confidence limit (LCL), 511
Lower explosive limit (LEL), 157, 562, 692–93
Lower flammable limit (LFL), 157
Lowest-feasible-level policy, for carcinogens, 843
Lung, 35–50; anatomy of, 39–41; edema, 185; volumes and capacities of, 45–46, 49–50
Lupus erythematosus, 63
Lyme disease, 427
Lymphatic vessel, 53

M
Macrophages, 47
Macula, 304
Macular degeneration, 102
Malignancy. See Cancer
Malleus, 85, 86
Management, role in occupational health, 4, 78–79, 802
Manganese poisoning, 131, 133, 172
Mannmade vitreous fibers (MMVF), 190
Mansdorf, S. Z., 78
Manual of Analytical Methods, 505, 507, 510, 511, 532, 539, 797
Manufacturers Association of Tri-County v. Krepper, 856
Marburg virus, 426
Marine terminal, 858
Maritime Safety Act, 808
Marshall, Ray, 842, 850
Marshall, Thurgood, 843
Marshall v. Barlow’s Inc., 846
Martin, Lynn, 872
Martin v. Occupational Safety and Health Review Commission, 861, 875
Maser, 16, 208
Mass spectrometers, 578
Mastoid air cells, 86, 89
Mastoiditis, 89–90
Material handling, 18, 378–79, 590
Material Safety Data Sheet (MSDS), 7, 9–10, 11, 144–47, 155–56, 750, 811–12; and EPA Hazardous Chemical Reporting Rules, 823; in hazard evaluation, 489; information resources, 147; and the Paperwork Reduction Act, 860–61, 864; for organic solvents, 154; training for, 604
Maximal oxygen uptake, 365
Maximal user output, 378
Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms, 236
Maximum use concentration (MUC), 682, 702
Maximum permissible dose (MPD), 274
Maximum permissible exposure (MPE), for lasers, 310–11, 312, 313
Maximum permissible load, 383
McBride, Lloyd, 849, 850
McGarity, Thomas, 876
McGowan, Carl, 830
“De Morbis Artificium Diatriba,” 207
Motion-related injury. See Cumulative trauma disorder
Motion time, 362
Motor nerve, 409
Motor vehicle safety, 868-69
Mucous discharge: of eye, 105–06
Mucous membrane, 37; hazards to, 68; of middle ear, 85; as natural defense, 48; penetration by infectious agent, 432
Mucus, 37, 48
Multisensor arrays, 577–78
Multispecialty group practice, 768
Muscle, 375, 408
Muscle strength, 375–76
Mutagen, 134
Mycobacterium, 427; marinum, 427; tuberculosis, 185, 423, 432, 448, 695
Mycoplasma, 421
Mycosis, 19, 427
Mycotoxicosis, 464
Mycotoxin, 463–64
Myopia, 102–03

N

Naegleria, 20, 427
Nail (finger and toe), 54, 60, 68
Narcotic, 161
Nasal cavities, 37
Nasal mucosa. See Mucous membrane
Nasal septum, 37, 59
Nasopharynx, 36, 37
National Academy of Science, 267, 420, 859, 878, 887. See also National Research Council
National Advisory Committee on Occupational Safety and Health (NACOSH), 830–31, 837, 882
National Association of Occupational Health Professionals, 767
National Cancer Institute, 466
National Committee for Clinical Laboratory Standards, 466
National Congress of Hispanic American Citizens (El congreso) v. Donovan, 857
National Congress of Hispanic American Citizens (El congreso) v. Usery, 857
National Council on Radiation Protection and Measurements (NCRP), 260, 267, 268, 272, 894
National Environmental Balancing Bureau (NEBB), 650
National Federation of Independent Business, 850
National Fire Protection Association (NFPA): fire hazard standards of, 154, 157; OSHA standards adopted from, 829; respirator standards of, 693; safety professionals' familiarity with, 749
National Foundation on the Arts and Humanities Act, 808
National Institute for Occupational Safety and Health (NIOSH), 6, 237, 489, 673, 818–20, 821; Appalachian Laboratory for Occupational Safety and Health (ALOSH), 818; assigned protection factors, 693; carcino-
gen, definition of, 133; criteria documents, 139, 159, 810, 819; Current Intelligence Bulletin (CIB), 139; Educational Resource Center (ERC), 7, 735, 819; establishment of, 138, 237, 809, 818; and Federal Coal Mine Health and Safety Act, 819; Health Effects Research Laboratory, 581; Health Hazard Evaluation (HHE) by, 7, 519, 819; hearing protective devices, 233; heat exposure guidelines, 13, 333, 338; Human Subjects Review Board, 819; latex allergies, 66; Manual of Analytical Methods, 505, 507, 510, 511, 532, 539; material handling guidelines, 383; noise exposure, 237, 240; occupational health nursing study by, 782; organic dust, 463; Pocket Guide to Chemical Hazards, 489, 692; Proficiency Analytical Testing Program, 532; Recommended Exposure Limit (REL), 6–7, 26, 152, 518; Registry of Toxic Effects of Chemical Substances (RTECS), 159; respirator certification by, 450, 601, 668, 673, 677–79; Respirator Design Logic, 690; sampling guidelines of, 187, 189, 502, 525, 544–60; skin injury statistics by, 56; sorbent tube recommendations of, 572, 573; standards development by, 819, 821; technical assistance to OSHA by, 489, 809, 810, 813; Testing and Certification Laboratory, 673, 819; training by, 819
National Institute of Environmental Health Sciences (NIEHS), 290
National Institute of Standards and Technology, 868
National Institutes of Health (NIH): biosafety guidelines, 431–34, 443, 466; Biosafety in Microbiological and Biomedical Laboratories (BMBL), 431, 436, 448, 450; on mine health advisory committee, 820–21
National Priority List (NPL) hazardous sites, 822
National Realty and Construction Co. v. OSHRC, 834
National Research Council: biosafety publications of, 433, 466; and Bureau of Labor Statistics reporting, 873; Committee on Human Factors, 357
National Response Center, 454
National Safety Council, 258, 466, 737, 895; resources available from, 755, 877; safety professional's familiarity with, 749
National Sanitation Foundation, 438, 466
National Science Foundation, 820
National Stone Associations, 856
National Toxicology Program, 160
Natural rubber latex (NRL), 65–66
Natural ventilation, 632
Natural wet bulb temperature, 337
Nearsightedness, 102–03
Neck tension syndrome, 411
Negative pressure respirator, 702–03
Negotiated Rulemaking Act, 874, 878, 882
Neoplasia. See Cancer
Neoprene, 166
Nerve, 361, 409
Neurasthenia, 131
Neurotoxic effect, 131

INDEX

1067
INDEX

Neutron, 14, 260, 261, 263
Neutron capture, 263
Neutron radiation, 14, 263
New Directions Grants Program, 847, 852, 876
New Jersey State Chamber of Commerce v. Hughey, 856
Newton's laws of motion, 173, 174, 374
Nickel allergy, 62–63
Nickel salt, 59, 172, 192
Night blindness, 106
Nitrate, 60
Nitric acid, 69, 58
Nitric oxide, 161, 569
Nitro compound, 153; biological effects of, 28, 59, 161; and solvent hazard control, 165
Nitroalkane, 161
Nitrobenzene, 153
Nitrogen, liquid, 131, 154
Nitrogen dioxide: and air pollution, 162-63; respiratory hazards from, 24, 47, 130; sampling device for, 524
Nitrogen oxide, 24
Nitrohydrocarbon, 161, 165
Nixon, Richard, 825, 832
No Observable Effect Level (NOEL), 127
No-effect level, 126, 519
Noise, 208, 220–21; continuous, 224–25; control methods for, 226–33; effects of, 11, 94–95, 94–97, 208; exposure factors, 217; exposure guidelines, 11–12, 218, 224, 845; exposure levels, in manufacturing, 207, 208; exposure monitoring, 238, 234, 238, 242–43, 498; from fan, 638; impact, 226; intermittent, 225; measurement of, 222–23; nonauditory effects, 95; nontechnical guidelines, 11; permissible levels of, 11–12, 216–17; protective equipment for, 229–30; reduction, 227; vs. sound, 208; synergistic effects, 504. See also Hearing; Sound
Noise dosimeter, 218, 221–22
Noise Reduction Rating, 233
Noise survey, 223–24
Nominal hazard zone (NHZ), for lasers, 314
Nomogram, 337
Northwest Airlines OSHRC review, 834, 850
Noise, 36–37, 50
Nuclear Regulatory Commission, 260, 267
Nucleus (of atom), 260, 261, 281
Nystagmus, 107

O
Observation, for hazard evaluation, 496–97
Obstructive bronchopulmonary disease, 46
Obstructive ventilatory defect, 46
Occupational exposure limits (OEL), 183, 697
Occupational Exposure Sampling Strategy Manual, 508
Occupational health and safety team, 4, 6, 164
Occupational health and safety technologist (OHST), 728–29
Occupational health hazards, definition of, 4
Occupational health nurse (OHN), 4, 775; certified (COHN), 777, 782; code of ethics, 778–81; functions of, 4, 6, 775, 784-91; role in occupational health program, 4, 782–84; scope of practice of, 776; standards of practice of, 776-77
Occupational health program, 443–44; goal of, 4; and industrial hygiene program, 800-02 models of, 782; OSHA evaluation of, 813–15
Occupational hearing conservationist (OHC), 235–36
Occupational medicine, 765
Occupational Medicine Board Examination, 767
Occupational medicine physician, 6, 765–73
Occupational Noise Exposure, 240, 242–55
Occupational physician, 6, 765–73
Occupational Safety and Health Act. See OSHAct
Occupational Safety and Health Administration. See OSHA
Occupational Safety and Health Reporter, 877
Occupational Safety and Health Review Commission (OSHRC), 808, 812, 818, 846, 861, 870, 875
Occupational safety and health technologist (OSHT), 746
Occupational skin disease. See Dermatosis
Occupied zone, 644
Octave-band analyzer, 220–21
Odor, 496
Office chair. See Seat
Office of Health and Safety Information System (OHASIS), 452
Office of Management and Budget (OMB), 854, 858, 860-61, 864
Office of Science and Technology Policy (OSTP), 433
Office of Technology Assessment (OTA), 489, 825, 882
Office workstation: design of, 392–405; health problems from, 395–96; and posture, 395–99
O’Hara (House subcommittee chair) and OSHA farm workers oversight hearing, 835
Ohio Manufacturers’ Association v. City of Akron, 856
Ohm’s law, 283, 285
Oil and gas drilling, 859
Oil, Chemical and Atomic Workers International Union, 808, 831, 848
Oil, Chemical & Atomic Workers International Union v. OSHRC, 848
Oil gland, 54, 55
Oil mist, 192, 201
Olefinic hydrocarbon, 144
INDEX

Olfactory nerve, 37, 131
OMB. See Office of Management and Budget
Omnibus Budget Reconciliation Act (OBRA), 867, 869, 873
Oncogen. See Carcinogen
Oncogenesis, 185
Open path infrared analyzer, 577
Ophthalmologist, 101
Ophthalmoscope, 102
Optical density (OD), 306
Optical radiation, 303; biological effects of, 108, 303–05; controls for, 306–07; exposure guidelines for, 305–06; measurement of, 317; photochemical effects of, 303, 307; protective eyewear for, 106, 111, 112; thermal effects of, 303. See also Infrared radiation; Laser; Ultraviolet radiation
Optician, 101
Opticians Association of America, 101
Optometrist, 101
Organ of Corti, 87
Organophosphate pesticides, 68, 502, 504
Occupational acne, 66–67
OSHA, 6, 138–39, 237, 489, 807–09, 895; air-sampling worksheet, 541–42; citation appeals, 816–17; citation by, 816, 828, 833, 846, 884, 885; “common-sense” enforcement policy of, 845–47; compliance activity, 812, 813, 869–71, 882–86; Compliance Manual, 828, 832–33; compliance programs for, 815–16; consultation service, 253–54, 851–52, 876; Cooperative Compliance Program (CCP), 878, 882–83, 884–885; cumulative trauma disorder program, 414; Division of Administration and Training Information, 733; Division of Training and Educational Development, 733; Division of Training and Educational Programs, 733; evaluation of, 876; Federal Agency Safety Programs, 841, 849; Field Inspection Reference Manual (FIRM), 812–13, 828, 871; field operations, 812–13; form 200 record-keeping log, 789–90, 814; hazard abatement verification, 883–84; home work place, 884; Industrial Hygiene Field Operations Manual (IHFOM), 833; inspection by, 812, 813–16, 827–28, 832–33, 846, 851–52; Integrated Management Information System (IMIS), 853; Job Safety and Health Quarterly, 875; jurisdictional issues, 832, 834–35, 850, 887; medical surveillance of PEL effectiveness, 502; National Emphasis Program (NEP), 833, 845; New Directions grant program, 847, 852, 876; occupational health program evaluation by, 815; Office of Training and Education, 732–33; petrochemical industry special-emphasis program (PetroSEP), 870; program structure, 826–27; recommendations on workplace violence, 882; reorganization of, 813; respiratory cleaning procedures, 722; respirator fit test protocols, 711–21; respirator medical evaluation questionnaire, 722–25; respirator user seal check procedures, 721–22; respiratory protection program, 725; sampling by, 517–18, 814–15, 816; State Plan Task Group, 853; state plans, 809, 827, 830–31, 836–37, 853, 856, 871–72, 888; Technical Manual, 511, 812–13; testing laboratory qualifications, 867; Toxic Substances List, 138–39; Training Institute, 733, 734, 735, 832, 876; training program for industrial hygienists, 603–05; Training Requirements in OSHA Standards and Training Guidelines, 798–800; tuberculosis infection control plan, 450; Voluntary Protection Program (VPP), 852, 876; Voluntary Training Guidelines, 604
OSHA Appropriations Act, 829
O SH Act, 6, 138–39, 237, 673, 755, 807, 825–26, 888; amendments, riders, and oversight, 835–36, 848–50, 873, 877; checks and balances for, 827; employee participation under, 827, 831, 847–48; employer responsibilities under, 826; enforcement of, 812, 826-27, 869–71; general responsibilities, 808–09; multi-employer citation policy, 885; NIOSH certification authorized by, 819; and occupational medicine, 766; provisions of, 809; standard-setting process defined by, 810; toxic substances list, 138–39; universal coverage, 826; whistle-blower provision, 831, 874, 885
OSHA’s Failure to Establish a Farmworker Field Sanitation Standard Hearing, 858
protection, 110, 307; for field sanitation, history of, 854, 857–58; for flammable and combustible liquid handling, 157; for general industry, 495, 808; for grain elevators, history of, 859, 867; Hazard Communication, 7, 138, 144, 489, 508, 604, 811–12, 815, 848, 855–56, 860–61, 863–64, 888; for hazardous waste management, history of, 810, 861, 867; Hearing Conservation Amendment, 97–98, 237, 839, 855; for indoor air quality, 649; for laser hazard, 16, 308–09; for lead, 599, 604, 839, 840, 844, 863–64, 874, 877, 879; for lighting, 317; for lockout/tagout (LOTO), history of, 866–67; logging, 881; longshoring, 877, 881; maritime, 808, 838, 856, 858, 881; for medical surveillance, 502, 810; 4,4-methylene (bis)-2-chloroaniline (MOCA), 838; methylene chloride, 878, 879; for methylenedianiline (MDA), history of, 854, 865; for monitoring exposure, 810–811; for motor vehicle safety, history of, 868, 881; NIOSH recommendations for, 819, 820–21; for noise, 11, 219, 224–25, 229, 237, 238, 240, 845; for oil and gas drilling, history of, 859; Occupational and Environmental Control, 811; performance, 810; permit-required confined spaces, 639; for personal protective equipment, 166, 466, 810, 878, 881–82; for pesticides, history of, 838–40; for power presses, history of, 868; for process safety management, 494–95, 604, 866; for protective clothing, 76; for radiofrequency and microwave exposure, 298–99; for record keeping, 815, 827, 832, 882; Regulatory Impact Analysis (RIA) required for, 839, 854; requested for chromium, 866; requested for tuberculosis, 466, 866, 869, 878; respirator selection, 689–90; for respirators, 508; for respiratory protection, 466, 602, 667, 671, 673, 684, 702–710, 815, 877, 879; for sanitation facilities regulation, 20, 74; setting process, 139, 809–11, 839, 840, 869, 874, 888; for shipyards, 808; for sound level meters, 216; start-up, 828, 829, 861, 881; for steel industry, 882; for sulfur dioxide, history of, 839; Toxic and Hazardous Substances, 810, 811; for training, 757, 811, 815, 827, 881, 888; for trichloroethylene, history of, 839; vertical, 810, 838; for vinyl chloride, history of, 689, 838, 840; violation of, 816–17, 886; for wheel rim servicing, history of, 858. See also Action limit; Permissible exposure limit; Short-term exposure limit; Time-weighted average

Ossicles, 85–86, 90–91

Osteoarthrosis. See Cumulative trauma disorder

Otitis media: nonsuppurative, 89; suppurative, 89

Otosclerosis, 90–91

Outdoor air, 632, 644, 651–53

Oval window (of ear), 85, 86

Overloading, 359, 364

Overuse disorder. See Cumulative trauma disorder

Oxalic acid, 58

Oxidizing material, 8, 28, 60, 617–18

Oxygen: acids, 150; and asphyxiants, 131; direct-reading monitor for, 567–68; in respiration, 35, 41–44, 365, 672

Oxygen-deficient atmospheres, 23, 703

Oxygen tension, 42

Ozone: atmospheric, 160, 163; hazards from, 24, 47–48, 130; monitoring of, 573

P

Pacemaker, 290, 291, 302

Pacinian corpuscle, 361

Pair production, 260

Paperwork Reduction Act, 860–61, 864

Papilla, 53

Paraformaldehyde, 441

Paraquat, 191

Parasite, 20, 28, 62, 420, 427

Parathion, 203

Parke, Barrington, 831

Paronychia, 68

Parotid, 90

Patch test, 65, 70, 72

Patty’s Industrial Hygiene and Toxicology, 159

PCB. See Polychlorinated biphenyl

Peak above ceiling, 183

Peak expiratory flow (PEF), 46

Peak expiratory flow rate (PEFR), 46

Pedal, 392

Pendergrass, John, 851, 859, 860, 865, 869

Penicillium, 200

Pentachlorophenol, 60, 203

Pentamidine, 695

People v. Chicago Magnet Wire Corp., 872

Perchloric acid, 154

Perchloroethylene, 160, 163, 591, 681

Peres, N. J. V., 406

Perilymph, 87

Perimeter, 102

Peripheral nervous system, 359, 360, 408

Peripheral neuropathy, 131, 159, 161, 500

Permanent threshold shift (PTS), 94

Permanent visual impairment, 114

Permanganate, 28

Permeability, 329
Permissible exposure limit (PEL), 25, 138–39, 183, 224, 829; and action level, 810; for airborne contaminants, 633, 861–62; for arsenic, history of, 844; for asbestos, 856, 863, 880; for benzene, 842, 865; for cadmium, history of, 865; for carbon tetrachloride, 160; and chemical inventory, 489; for coke oven emissions, history of, 841; for cotton dust, history of, 843, 864–65; for formaldehyde, history of, 865; for glycol, 162; for lead, 845, 863–64, 879; for methylenedianiline, history of, 865; noise dose, 225; for particulates, 178; proposed for butadiene, 865, 879; proposed for carbon disulfide, 881; proposed for gluteraldehyde, 881; proposed for hydrozine, 881; proposed for methylene chloride, 865, 869; proposed for trimellitic anhydride, 881; and sampling, 508; setting procedure for, 138, 839, 840; for solvents and gases, 151–52

Permissible heat exposure limit (PHEL), 341

Personal hygiene, 598–99; and dermatosis, 63, 74–75; for radioactive particulate control, 198; for solvent hazard control, 166; for thermal stress control, 344

Personal monitoring (sampling), 498–99, 506, 523

Personal protective equipment, 30, 76–78, 279, 586, 753; for biological hazards, 454–55; for building-related illness control, 458; clothing, 76–77, 151, 158, 166, 440, 602–03; OSHA requirement for, 600, 810, 815, 839; protective eyewear, 166–67; respirators, 165, 603; for skin, 74–75; for solvents, 165–67; for thermal stress, 348, 354; for tuberculosis, 450; and weather, 63; for zoonotic diseases, 426. See also Gloves; Hearing-protective device; Protective eyewear; Respirator

Perspiration. See Sweat

Pesticide, 60, 172; history of OSHA regulation of, 838, 840

Petroleum products, 59, 133, 159

Pfiesteria piscicida, 465

Phalen's test for carpal tunnel syndrome, 409

Pharynx, 37, 50

Phase-contrast microscopy (PCM), 197

Phenol, 58, 69, 153

Phenolic, 440, 441

Phenyldiazine, 59

Phenylmercury compound, 59

Phoropter, 102

Phosgene, 47, 130, 573

Phosphorus pentoxide, 28

Photocoustic spectrometer, 577

Photallergy, 55, 66

Photoelectric effect, 260

Photoionization detector, 575

Photon, 260

Photopatch test, 70

Photophobic eye, 106

Photosensitivity, 66

Photosensitizer, 61, 62, 66

Phototoxicity, 66

Phototropic lenses, 112

Physical examination. See Medical examination

Physical hazard, 7, 11–17, 61–62, 107–09. See also Noise; Heat stress

Physician or other licensed healthcare professional (PLHCP), 703

Picric acid, 28, 58

Pigmentary abnormalities, 67

Pink eye, 105–06

Pitch. See Petroleum products

Pitot-tube devices, 626

Plant toxin. See Biological toxin

Plasmodium, 421

Pleural effusion, 40, 47

Pleurisy, 40, 47

Plutonium, 178, 260, 278

Pneumoconiosis, 8, 46, 47, 132, 171, 173, 183, 185, 202; coal workers’, 185; from dust, 171

Pneumonia, 24, 47

Pneumonitis, 47, 158

Pneumothorax, 40

Pocket Guide to Chemical Hazards, 489

Polarity (of electric field), 281

Polarization, 295

Polarized light mineralogical analysis (PLM), 197

Polarographic detector, 568

Poliovirus vaccine, 431

Polychlorinated biphenyl (PCB), 192, 500

Polycyclic aromatic hydrocarbon (PAH), 316, 524

Polyvinyl aromatic hydrocarbons (PAH), 189, 201

Polyol, 161

Polyvinyl alcohol (PVA) gloves, 166

Potassium cyanide, 58

Potassium hydroxide, 58

Potentiometer, 569

Powered air-purifying respirator, 682–84, 703

Portable gas chromatographs, 578

Positive-pressure respirators, 700–01, 703

Positron, 262

Postal Employees Safety Enhancement Act, 887

Posture, 396–401

Potash, 28

Potassium cyanide, 58

Potassium hydroxide, 58

Potentiometer, 569

Powered air-purifying respirator, 682–84, 703

Practice for Occupational and Educational Eye and Face Protection, 110, 167

Practices for Respiratory Protection for the Fire Service, 693

Precision rotameter, 538–39

Pregnancy. See Reproductive hazard; Teratogenesis

Preliminary noise survey, 223

Preplacement examination, 772

Presbycusis, 92, 208, 215

Presbyopia, 102, 104
INDEX

Pressure, 16; and air movement, 620–25; and air sampling, 539; changes, in respiration, 43–44; compensating devices, 531
Pressure demand respirator, 703
Preventing Illness and Injury in the Workplace, 825
Prickly heat, 67, 331
Primary irritant: dermatitis from, 28, 55–56, 57, 61, 62, 63, 64, 158; respiratory effects of, 129
Primary open-angle glaucoma (POAG), 106
Prion, 171, 421
Process analysis, 487
Process flow sheet, 490, 492–93
Process modification, 30, 591–92; for noise control, 227; for skin hazard control, 72–73; for solvent hazard control, 164–65
Process safety management, 494–95, 866
Professional engineer, 762
Prokaryote, 421
Pronator (teres) syndrome, 412
Propanol, 161
Propeller fans, 638
Proprioceptor, 361
Prospective study, 137–138
Protective clothing. See Personal protective equipment
Protective eyewear, 166–67, 603; fitting, 113, 114; goggles, 110, 167; for lasers, 111, 314; for optical radiation hazards, 111, 304, 603; plastic vs. glass, 110; for solvent hazard control, 166–67; for visual display terminal use, 111–112; for welding, 111, 603
Protein allergen, 19, 28, 420
Protein precipitants, 28, 61
Proton, 260, 261, 281
Protozoa. See Microorganism
Proximal stimulus, 362
Pruritus, 72
Pseudomonas, 421
Psittacosis, 422, 426, 430
Psoriasis, palmar, 63
Psychological hazard, 488
Psychometric wet bulb temperature, 336
Public Citizen, 852, 854, 855
Public Citizen Health Research Group v. Auchter, 858
Public Citizen Health Research Group v. Tyson, 858
Public Health Service, 6, 454, 818, 822
Public Law 91-173. See Federal Mine Safety and Health Act
Public Law 91-596. See OSHA Act
Public Law 85-742. See Maritime Safety Act
Public Law 91-54. See Construction Safety Amendments
Pulaski v. California Occupational Safety and Health Standards Board, 888
Pulmonary edema, 47, 48, 158, 183, 185
Pulmonary mycosis, 430
Pulmonary ventilation, 49–50, 124
Puncture. See Laceration
Pupil, 101, 303
Purging (dilution ventilation), 634–36
Pus, 106
Pyrethrum, 60
Pyroelectric detector, 317
Q
Q fever, 188, 422, 425, 426, 427, 430
Q-switching, 309, 316
Qualitative fit testing, 696–97, 703, 712–17; irritant fume protocol, 698; isoamyl acetate protocol, 697; saccharin and Bitrex solution aerosol protocol, 697–98
Quality factor (Q), 260, 263
Quantitative fit testing, 698–99, 703, 717–21; protocol, 699–700
Quantum detector, 317
Quatrz. See Silica dust
Quaternary ammonium compound, 440
Quick Selection Guide to Chemical Protective Clothing, 602
R
Rad, 260
Radar, 281
Radial-blade fans, 615
Radian, 305
Radiant heat, 12–13, 347, 349, 603
Radiant heat exchange rate, 328
Radiation. See Ionizing radiation; Nonionizing radiation; specific radiation
Radiation counter, 15, 270
Radiation field, 264
Radiation-producing machine, 276
Radiation Protection Guides, 272
Radiation safety committee (RSC), 443
Radioactive decay, 264
Radioactive metals, 277
Radioactive particles, 198
Radioactivity. See Ionizing radiation; specific radiation
Radiodermatitis, 62
Radiofrequency radiation, 293–94, 295–301; biological effects of, 15, 295–99; control of, 302–03; dosimetry, 295–96; exposure guidelines for, 297–98; field vs. radiation, 285–87; measurement of, 299–301
Radioisotope, 188, 260, 275, 276–77
Radionuclides, 684
Radiospectroscopy, 198
Radon, 260
Radon progeny, 188
Ramazzini, Bernadino, 170, 207, 406, 765
Randot stereo test (depth perception), 105
Raoult's law, 151
Rarefaction, 208, 212
Rate of convective heat exchange by respiration, 329
Rate of evaporative heat loss, 329
Rate of evaporative heat loss by respiration, 329
Rating of perceived exertion, 367
Raynaud’s phenomenon, 18, 63, 68, 409, 413, 351
Reaction time, 362
Reactive scrubbing, 617
Reactivity, 151
Reagan, Ronald, 839, 851, 854
Receiving hood, 611
Recombinant DNA, 420, 425, 443
Recommendations for the Safe Use and Regulation of Radiation Sources in Industry, Medicine, Research and Teaching, 267
Recommended alert limit (RAL) for heat stress, 338
Recommended exposure limit (REL), 7, 26, 152, 183; and chemical inventory, 489; for heat stress, 338
Recommended weight limit (RWL), 383
Record keeping, 800; for hearing conservation program, 240, 246; OSHA form 200 log, 789–90; OSHA requirement for, 815, 827, 832, 839; of work-related illnesses and injuries, 878, 882
Redesigned Occupational Safety and Health (ROSH), 873
Reducer, 61
Reflective clothing, 349
Reflection equipment, 102
Refrigerant, 160–61
Regional musculoskeletal disorder. See Cumulative trauma disorder
Registry of Toxic Effects of Chemical Substances (RTECS), 138, 159, 519
Regulated area, 815
Regulatory Impact Analysis (RIA), 839, 854
Relative humidity (RH), 681–82
Renal injury, 48
Renovation workers, 427
Repetitive motion injury. See Cumulative trauma disorder
Repetitiveness, 407
Reproductive hazard, 134, 429; from glycol, 162; from ionizing radiation, 267–68; from lead, 134, 861; from radiofrequency and microwave radiation, 295; and United Auto Workers v. Johnson Controls Inc. decision, 135, 861. See also Teratogenesis
Residential Lead-Based Paint Hazard Reduction Act, 821
Residual volume (RV), 45, 46
Resin, 7
Resource Conservation and Recovery Act (RCRA), 600, 821–22
Respirable dust curves, 190
Respirable mass fraction, 190
Respiration, 41–46
Respirator, 165, 600–02; aerosol-removing, 675–79; air-line, 601, 684–86; air-purifying, 450, 601, 675–84; air-supplying, 601; assigned protection factor (APF), 696; atmosphere-supplying, 684–88; classes of, 673, 675–88; cleaning procedures, 722; combination aerosol filter/gas or vapor removing, 675–82; combination air-purifying and atmosphere-supplying, 688; combination self-contained breathing apparatus and air-line, 688; for fire fighting, 692–93; fit testing, 669–70, 696–701; gas/vapor-removing, 680–82; for health care facilities, 695; maintenance and storage, 671–72, 707–08; medical aspects of use of, 502; positive-pressure, 700–01; powered air-purifying, 682–84; regulations for, 673, 877; selection of, 600–01, 667, 668, 688–96, 704; self-contained breathing apparatus, 686–88; for solvents, 165; for tuberculosis control, 450; user seal check, 670
Respiratory center, 45, 131
Respiratory hazard, 22–24, 47–48, 129; causes of, 171, 172–73; determination, 690–91
Respiratory inlet covering, 702
Respiratory protection program, 450, 600–02, 668–73, 689, 703–04; administration, 672–73; evaluation, 710; record keeping, 710; worksite-specific procedures, 668
Respirator Selection Table, 689
Respiratory system, 36–37, 41–46, 132; natural defenses, 48; and particulates, 181–82; schematic drawing of, 36
Response time, 362
Restrictive ventilatory defect, 46
Reticular dermis, 53
Retina, 100, 101, 105; inflammation of, 106; radiation effects on, 303–04
Retinal pigmented epithelium (RPE), 304
Retrospective study, 137
Return air register, 645, 647
Rheumatic disease. See Cumulative trauma disorder
Rhinitis, 46, 65, 459
Ribavirin, 695
Rickettsia, 425
Rickettsial agent, 425
Ridder, seat designs of, 402
Risk assessment. See Evaluation
Risk management, 759–60
Rocky Mountain spotted fever, 427
Rod monochromatism, 105
Rods (of retina), 101, 105, 303–04
Roentgen, Wilhelm, 265
Roentgen (R), 260
Roentgen absorbed dose (rad), 260
Roentgen equivalent man (rem), 260
Roentgenogram. See X ray, diagnostic
Root-mean-square (rms) sound pressure, 212
Rosenstock, Linda, 869
Rosin, 60
Rotating vane anemometer, 626
Roteneone, 60
Round window (of ear), 85, 86
Route of entry (of hazardous material), 11, 20–21, 124–25. See also Absorption; Ingestion; Inhalation; Injection
Rowland, Robert, 851, 857
Rubber manufacturing, 60, 79
Rubella, 134, 429
INDEX

Rubner, contributions to ergonomics by, 358
Ruffini organ, 361
Russian spring summer fever, 427

S
S. A. Healy v. OSHRC, 886
Saccharin and Bitrex solution aerosol protocol, 697–98
Safe Handling of Radionuclides, 276
Safety and health committee, 6, 79, 794, 802
Safety Equipment Institute (SEI), 573
Safety Fundamentals Examination, 762
Safety glasses. See Protective eyewear
Safety inspection, 752–53
Safety investigation and analysis, 753–54
Safety in the Federal Workplace Hearings, 841
Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 297
Safety professional, 4, 743–64; associate (ASP), 762; certified (CSP), 761–62; codes and standards, 749; duties of, 78–79; equipment purchasing, 802; and industrial hygienist, 802; and safety inspections, 753; scope and function of, 743–47
Safety program, 802
Safety technician, 753
Salmonella, 136, 423, 432
Salt, 344. See also Metallic salt
Sample collection device, 524; for gases and vapors, 524–27; for particulates, 524–31
Sampling, 505–12; absorption, 525; accuracy and precision of, 510–12; active, 571; adsorption, 525–27; area, 499–500, 506–07; collection device for, 524–31; direct-reading instrument for, 508; endotoxins, 462; environmental, 459-60; and exposure guidelines, 525–27; grab, 505, 524; integrated, 524, 525–27; method, 506–10; by OSHA, 814–15, 816; passive, 527, 571–72; personal, 498–99, 506; record keeping for, 508; results interpretation, 516–19; of water, legionellae, 456–57; and workplace design, 590. See also Air sampling; Biological sampling; Evaluation; Monitoring
Sampling and analytical error (SAE), 511
Sampling pump, 498–99, 524
Sampling train, 524, 536
Samuel, Howard, 850
Sanitation facilities, 20, 73–74
Sawtooth waveform, 301
Scannel, Gerard, 860
Scanning electron microscopy (SEM), 197
Schistosoma, 427, 428
Scholz, John T., 877
Schweiker, Richard, 849
Schwope, A. D., 78
Scintillation counter, 260, 270
Sclera, 100, 101
Scotoma, 304
Scrapie, 421
Scuba diving. See Diving
Seat, 398–99, 400–03; stand-seat, 392, 393
Sebaceous gland, 54
Second-degree burns, 69
Secondary irritant, 129
Secretary of Labor. See Department of Labor
Secretary v. Arcadian Corporation, 884
Secretary of Labor v. Union Tank Car Co., 882
Sedimentation (particle settling), 174, 675
Self-contained breathing apparatus (SCBA), 671, 693, 703; closed circuit, 686–87; escape, 688; open circuit, 687
Selikoff, Irving, 825, 841
Sensitization dermatitis. See Dermatitis, allergic contact
Sensitizer, 63, 64; and chronic exposure, 128; dermatitis from, 61, 65, 64–65. See also Allergen, biological
Sensorineural hearing loss, 92
Sensory nerve, 409
Sensory perception, 495–96
Serum banking, 444
Service Contracts Act, 808
Service life, 703
Sewage, 20, 427
Sex, 62–63
Shapiro, Sidney, 876
Shaver’s disease. See Pneumoconiosis
Sheehan, Jack J., 830
Sheet Metal and Air Conditioning National Association (SMACNA), 650
Shellac, 60
Shielding, 260, 272–74, 277, 293; for heat stress control, 599; for radiation and radiant heat, 302–03, 599. See also Containment; Enclosure; Isolation
Shigella, 423
Shivering, 350
Short-circuiting, 639–40
Short-term exposure limit (STEL), 25, 140, 183, 489; for asbestos, 863; for benzene, 865; for carbon tetrachloride, 160; for ethylene oxide, 858, 863; for formaldehyde, 864; OSHA setting procedure for, 839; and sampling time, 508
Sick-building syndrome (SBS), 20, 459
Sievert (Sv), 260
Sight. See Vision
Silane, 154, 158
Silica gel tubes (adsorption), 527
Silica dust, 24, 173, 178, 182, 191
Silicates, 173
Silicon dioxide. See Silica dust
Silicosis, 46, 47, 173, 178, 182, 183, 185, 529
Simian immunodeficiency virus (SIV), 426
Simple reaction time, 362, 364
Sin nombre hantavirus, 426
Sine waves, 283
Single-zone constant-volume system (HVAC), 644–645
Sinus, 16
Sitting, 392, 397–99, 401-03
Skin, 51–56; chemical absorption, 690; cold hazard to, 352;
defense mechanisms, 55–56; radiation effects on, 262,
304–05; and thermal balance, 330. See also Dermatitis;
Dermatosis
Skin irritation. See Dermatitis; Dermatosis
Skin notation, 25, 69
Sling psychrometer, 653
Slit-lamp microscope, 102
Slot hood, 611
Smair ring, 194
Smog, 162–63
Smoke, 22, 171
Smoke tube tests, 625, 640, 653
Smoking. See Cigarette smoking
Sneeze, 48
Snellen chart, 101–02, 104
Snook, S. H., 384–86
Soap, 60
Soap-bubble meter, 536-37
Soap stone, 191
Society for Healthcare Epidemiology of America (SHEA),
425, 466
Society of Manufacturing Engineers, 894
Society of Plastics Industry, Inc. v. OSHA, 840
Society of Toxicology, 894
Sodium, 59
Sodium cyanide, 58
Sodium hydroxide, 58, 173
Sodium hypochlorite, 440
Software. See Computerized industrial hygiene system
Solid-state scintillator, 198
Solid Waste Disposal Act, 821
Solubility, 150
Solute, 150
Solvent, 28, 149, 150; biological effects of, 8, 11, 28, 59, 61,
159–62; classification of, 152–54; control methods for,
164–67; evaluating hazard of, 163–64; information refer-
ces, 154; organic, 61, 150, 152–54, 159; properties of,
150; sampling monitor for, 566
Solvent-repellent cream, 75
Somatic nervous system, 361
Somesthetic sensors, 361
Sorbent cartridges and canisters, 672
Sound, 208; generation, 208; human reaction, 215; vs.
noise, 208; power, 212–14; pressure, 212, 213; pressure
level, 212–15; properties of, 94, 208–16; surveys,
222–26; weighting, 216. See also Hearing; Noise
Sound level contour, 222, 224
Sound level meter, 218–20, 224
Sound power level, 212–14
Sound waves, 210; diffraction, 211
Southern Railway v. OSHRC, 834
Specific absorption (SA), 295
Specific absorption rate (SAR), 295, 296, 297
Specification for Personal Noise Dosimeters, 222
Specifications for Audiometers, 234, 236
Spectacles, protective, 110
Spectrometer, 576–77
Spectrophotometer, 576–77
Spectroscopic analysis, 195
Spectrum, 211
Speech, 39; hearing, 96, 217
Speed of light, 283, 285
Speed of sound, 211–12
Spill. See Cleaning and maintenance
Spina Bifida Association of America, 66
Spinal cord, 361
Spinal nerves, 361
Spiral absorber, 525
Spiretometry, 46, 536, 669
Spot-checking, 760
Stachybotrys chartarum, 199, 464
Stack, exhaust, 612-15
Standard operating procedure (SOP): for industrial hygiene
program, 794–95
Standard Practice for Measuring the Concentration of Toxic
Gases or Vapors Using Length-of-Stain Dosimeters, 571
Standards of Occupational Health Nursing Practice, 776–77
Standing, 392, 397, 40
Stapes, 85-86
Staphylococcus, aureus, 63, 424
State and local regulations: ANSI and NFPA standards, 821;
before OSHAct, 807; under OSHAct, 809, 827, 830,
836–38, 853, 856, 861, 871–72; right-to-know law, 812,
856
State Implementation of Federal Standards Hearings, 853
Static muscle tension, 407
Static pressure, 621–22; measurements, 627–29
Static pressure regain, 612
Static strength, 376
Static work, 18–19
Statistical method of analysis, 754
Steiger, William A., 826, 836, 837
Stender, John H., 832, 833, 835, 837
Stenosis, 89
Stereadian, 305
Stereoscopic vision, 101, 105
Sterilization, 440
Stevens, John Paul, 843
Stevens's rating of perceived exertion, 367
Storage, 165; of dangerous chemicals, 8
Strain, 408
A Strategy for Assessing and Managing Occupational Exposures,
796
Stratum corneum, 55, 64, 304
Stratum malphigii, 304
Strength, 376–78
Strontium-90, 260
Strunk, Dorothy Y., 732
INDEX

Styrene, 500, 681
Subcutaneous layer, 53
Subradiofrequency radiation: biological effects of, 290–91; control methods for, 293; field strength, 287; measurement of, 291–92; static magnetic field, 289–90; time-varying, 290–91; uses of, 288
Substitution of equipment, 29, 227
Substitution of material, 29, 73, 591
Substitution of process. See Process modification
Suction pump (for air-sampling device), 531; calibration parameters for, 536–39; primary calibration, 536–37; secondary calibration, 538–39
Sulfur dioxide, 38, 47, 130, 524, 839
Sulfur hexafluoride, 576
Sulfuric acid, 24, 28, 58, 69, 151, 201
Sunburn, 16, 55, 88, 304–05
Sunglasses, 112
Sunlight, 16, 55; effects on skin, 16, 28, 55, 62, 68; and eye protection, 106; natural defense against, 55, 304
Supernaurl protector, 232
Superfund, 822
Superfund Amendments and Reauthorization Act (SARA), 822, 854, 867, 874
Superfund Extension Act, 882
Supervisor: role of, 757; training, 757, 759
Supply air, 644
Supply diffuser, 644
Supreme Court, decisions affecting OSHA, 843-45, 846, 848, 854–55, 867, 874, 882
Surface acoustic wave detectors, 577
Surface lipid film, 55, 61
Surface sampling, 193–94
Surface Transportation Assistance Act, 874
Susceptibility, 428–29
Swallowing, 38
Sweat, 53, 54–55; and dermatosis, 62; reactions, 67; and thermal balance, 330, 343, 344
Sweat gland, 53–54
Swedish Board for Technical Accreditation (SWEDAC), 302
Swedish Confederation of Professional Employees (TCO), 302
Swinging vane velometer, 625
Synergism. See Antagonistic action
Synovial fluid, 408
Synovitis, 409
Synthetic Organic Chemical Manufacturers Association v. Brennan, 841
Systemic toxin, 7, 131, 420; particulate, 170; and skin, 68–69
Systems safety, 754, 760–61
T
Talc, 191
Tannic acid, 28
Target organ, 296
Tarsal gland, 100
Taylor Diving and Salvage Co. v. Department of Labor, 841, 844
Tears, 100
Teeth, 16
Telangiectasia, 68
Temperature: and concentration calculation, 637; extremes, 12, 28, 56, 61, 350; and hazard monitoring equipment, 567; and indoor air quality, 653; measurement of, 12–13, 336–37; outdoor, 327; and vapor pressure, 151. See also Body core temperature; Cold stress; Heat stress
Temperature regulation. See Thermal balance
Temporary threshold shift (TTS), 94–95
Tendinitis, 399, 409
Tendon, 408
Tennis elbow, 411
Tenosynovitis, 17, 409
Teratogenesis, 134; and fetal infection, 134; from lead, 134; from radiation, 295; and United Auto Workers v. Johnson Controls Inc. decision, 135, 861
Terminal devices, 647
Testes, 287, 296
Testing and balancing (HVAC system), 650
Tetrachloroethylene, 68, 160
Textile workers, 427
Thallium, 173, 184
Thermal balance, 54–55, 56, 328-29, 350
Thermal comfort zone, 353–54
Thermal conductivity detector, 562, 575, 576
Thermal detector, 317
Thermal stress. See Cold stress; Heat stress; Temperature, extremes
Thermo-anemometer, 625–26
Thermoluminescence detector (TLD), 268–69
Thermoregulation. See Thermal balance
THERP, 761
Third-degree burns, 69
Third-party inspections, 753
Thoracic cage, 44
Thoracic outlet syndrome, 409, 412
Thoracic Particulate Mass (TPM), 191
Thorium, 173
Threshold audiogram, 234
Threshold audiometry, 234
Threshold Limit Value (TLV), 24, 139, 140, 183, 739; adopted as OSHA standard, 138, 809, 810, 829, 861; adopted by states before OSHAct, 807; for aliphatic hydrocarbons, 159; by animal experimentation, 136; for aniline, 690; for benzene, 160; for cadmium oxide, 48, 191; for carbon monoxide, 517; for carbon tetrachloride, 160; for chemical asphyxiants, 131; and chemical inventory, 489; for coal dust, 191; for cold stress, 352; and concentration of airborne contaminant, 633; diquat dibromide, 191; documentation of, 141–42; for direct current electric fields, 289; for fluorine, 160; for...
formaldehyde, 570; graphite, 191; for heat stress and strain, 13, 333–35, 338, 341; for impact noise, 226; limitations, 139–40; for mica, 191; for mixtures, 140–41; for nitropropane, 161; for noise, 11; for nuisance dusts and aerosols, 190; for optical and infrared radiation, 306; for paraquat, 191; for particulates, 24–25, 132; for static magnetic fields, 290; for subradiofrequency fields, 291; and synergism, 504; talc, 191; for trichlofluoromethane, 161; for 1,1,1-trichloroethane, 160; and unlisted substances, 141

Threshold Limit Values and Biological Exposure Indices, 13, 25, 69, 139, 144, 465; skin notation, 25

Threshold of effect, 126

Threshold of hearing, 212

Threshold of pain, 212

Tidal volume (TV), 45, 46

Tight-building syndrome, 459

Tight-fitting facepiece, 703

Time-weighted average (TWA), 25, 26, 140; calculation of, 140; and chemical inventory, 489; for ethylene oxide, history of, 821; as legal requirement, 810; for metabolic rate, 336, 338; for noise, 11, 223, 238, 239, 240; OSHA inspector’s determination of, 814–15; OSHA setting procedure for, 839; for radiofrequency and microwave radiation, 297–98; and recommended exposure limit, 139; and sampling, 499, 508, 524; for static magnetic fields, 290

Tinnitus, 92

Titmus “Fly,” 105

Toluene, 68, 153, 161, 164, 504, 681. See also Aromatic hydrocarbon

Toluene diisocyanate (TDI), 573, 579

Tonometer, 102

Tonsil, 37

Topical steroids, 106

Torque, 374

Total lung capacity (TLC), 46

Toxic chemical, 11, 123. See also Chemical hazard; Toxicity

Toxic effect, 123

Toxicity, 123, 124, 126; acute, 128; chronic, 136; vs. hazard, 11, 124; and hazard evaluation, 163, 487; and in-vitro testing, 136; local, 124

Toxicological screening, 136

Toxicology, 123; information resources, 147

Toxicology and Biochemistry of Aromatic Hydrocarbons, 159

Toxic Substances Control Act (TOSCA), 138, 821

Toxic Substances List, 138–39

Toxic use reduction (TUR), 493

Toxoplasma, 421, 432

Toxoplasmosis, 426, 429

Tracer (radioactive), 260

Tracer gas airflow calculation, 651–53

Trachea, 37, 38, 39, 50

Tracheitis, 39

Training: and biosafety, 444; for cold stress control, 352; hazard control, 603–05; for hearing conservation, 239, 246; for heat stress control, 344; as industrial hygienist, 732–34; for lifting, 379–82; OSHA industrial hygienist, 732–34; and OSHA requirement for, 811, 812, 815, 827, 839; by NIOSH, 819; for respirator use, 671, 709–10; safety and health, 603–05, 756–59, 786, 798–800

Training Requirements in OSHA Standards and Training Guidelines, 799

Tends, 362

Transmission electron microscopy (TEM), 197, 198

Trauma, 61

Traverse, 626

Treatment, storage, and disposal (TSD) facility, 822

Tremolite, 180, 856, 863

Trench foot, 351

Tritium, 260

Tumor, cutaneous, 67–68

Tumorigen. See Carcinogen

Turbinates, 37

Turpentine, 59

T wave, 290

Tympanic membrane. See Eardrum

Typhoid fever, 422

Tyson, Patrick R., 851, 857

U

U-tube manometer, 620–21

UAW, Brock v. General Dynamics Land Systems Division, 298, 317

Ulceration: of mucous membrane, 68; of skin, 68

Ulnar artery aneurysm, 413

Ulnar nerve entrapment, 413

Ultra high efficiency air (ULPA) filter, 175

Ultraviolet light, 55, 575

Ultraviolet light-sensitive disease, 63

effects of, 55, 303, 306; protective eyewear for, 111; threshold limit values, 141
Ultraviolet spectrophotometer, 569
Underloading, 359, 364
Underwriter Laboratories, 531, 895
Union occupational health physicians, 769
United Auto Workers v. Johnson Controls Inc., 135, 861
United States Pharmacopoeia, 672
United Steelworkers, 879
United Steelworkers of America v. Auchter, 855
United Steelworkers of America v. Pendergrass, 856
United Steelworkers v. Marshall, 845
Unit size principle, 382
Unit ventilator, 646
Universal Construction Company Inc. v. OHSRC, 885
Upper confidence limit (UCL), 511
Upper explosive limit (UEL), 157, 562
Upper flammable limit, 157
Uranium, 173, 178, 179–80, 188, 260, 277
Urine testing, 143, 144, 500
Urquhart, Michael, 859
Urticaria, 65–66, 78
User seal check, 703, 721–22
Uvea tract, 106
Uveitis, 105–06
Vaccination, 444
Vanadium pentoxide, 203
Vanderbilt, R. T., 856
Vanexial fan, 638
Vanishing cream, 75
Vapor, 22, 148, 524; adsorption of, 617, 680; biological effects of, 22, 23, 64, 108; concentration calculation, 512–13; control methods for, 617–18; equivalents, 513–14; flammable range, 157; properties of, 150; sampling monitors for, 192, 524–27; toxic, 23
Vapor pressure, 150
Vaporphase water, 150
Variability of response, 488
Variable air volume (VAV) system, 507, 644, 645–46, 647
Varicella, 459
Vasodilator, 160
Velocity, 211–12; pressure, 621–22
Venezuelan equine encephalitis, 422
Ventilation, 30, 72, 139, 165, 586, 595–97; airflow principles, 618–20; for asphyxiant control, 158; for heat stress control, 346, 347; natural, 595; for solvent hazard control, 165; tests of pulmonary function, 49–50; and tuberculosis control, 451. See also Dilution ventilation; Exhaust ventilation; HVAC system
Vertigo, 92, 106, 161
Vestibular sensor, 361
Vestibule (of inner ear), 87
Veterinary practice. See Animals
Viability, 428
Vibration, 208; hazards from, 18, 68, 409; of hearing device, 230; and sound generation, 208
Vibration syndrome. See Raynaud’s phenomenon
Vibrissae, 84
Video display terminal (VDT), 111–12, 293, 301–02, 399.
See also Office workstation, design of
Vinyl chloride, 61, 136, 681, 838, 840
Viroids, 421
Virulence, 428
Virus, 20, 62, 171, 199–201, 420–21. See also Microorganism
Visceroceptor, 361
Visible light. See Lighting; Optical radiation
Vision: acuity of, 104–05, 113, 115; of color, 105; and dark adaptation, 105; and depth perception 101, 105; evaluation of, 101–02; impairment of, 107–09, 115; loss, 114; testing, 101–02; and workstation design, 399. See also Eye
Vision conservation program, 113–14
Vision screening device, 113
Visitron v. OSHA, 840
Visual acuity, 104–05, 114
Visual display terminals: eye protection, 111–12
Visual field, 114
Vital capacity (VC), 46, 49–50
Vitiligo, 53, 67
Vitreous humor, 100, 101, 303
Vocal cord, 38, 39
Volumetric airflow, 640
Voluntary Training Guidelines, 604
von Meyer, biomechanical research of, 374
Wald, Patricia, 880
Walkthrough, 495
Walsh–Healey Asbestos Standard, 829
Walsh-Healey BD standard, 879
Walsh–Healey Public Contracts Act, 237, 808, 827, 829, 861
Wart, 67–68
Water, potable, 20
Water loss. See Dehydration
Water-repellent cream, 75
Water system, 348–49
Wave length, 211
Weather, and dermatosis, 63
Wedum, Arnold G., 420
Weight-per-unit volume, 514
Weighted-frequency scale, 216
Weil, David, 877
Weisberg, Stuart E., 875
Weighting networks, 219
Welding arc: eye protection for, 111, 307; hazards from, 15, 111, 304
INDEX

Welding fumes, 175
Wellness program, 786–87
West Nile virus, 431
Wet bulb globe temperature (WBGT), 13, 333, 335, 336, 337–38, 341
Wet bulb temperature, 12–13; natural, 337; psychrometric, 336
Wet process, 29, 597–98
Wet scrubbers: for air cleaning, 616
Wet-test meter, 538
Wet wiping process, 194
What-if scenario, for process safety management, 495
Wheatstone bridge circuit, 562, 563, 576
Whirlpool Corp. v. Marshall, 848, 885
White finger. See Raynaud’s phenomenon
Whiting, Basil, 836, 847, 850
Williams, Harrison A., 842
Williams–Steiger OSHAct of 1970. See OSHAct
Willow Island, West Virginia Cooling Tower Collapse Hearings, 849–50
Windchill index, 14, 351
Wirtz, William, 825
Wiseman, Donald G., 875
Wood dust, 173, 427
Woodprocessing, 427
Work, classification of, 366-67
Work capacity, 364–69
Work demands, and thermal balance, 329, 348
Workers at Risk—The Failed Promise of the Occupational Safety and Health Administration, 877
Workers’ compensation: hearing conservation program, 238; for injury or impairment, 70–72, 114, 207–08; and occupational medicine, 789
Workers’ Family Protection Act, 874
Working Group on Civilian Biodefense, 454
Workload, mental, 364–65
Workplace: and associated hazards, 423–25; design of, 19, 392–405; design of, for hazard control, 382–83. See also Building-related illness
Workplace violence, 882
Work-practice control, 440, 815
Work/rest cycles, 367–68
Work schedule as hazard control method, 30, 348, 353
Work seat. See Seat
Workplace Exposure Evaluation Levels (WEELs), 183
Workstation, 392–96. See also Office workstation
World Health Organization (WHO), 148, 291, 333, 431, 436
Written Injury and Illness Prevention Program, 604–05
X
X-radiation, 15, 261, 263, 286; dermatosis from, 28, 62
X ray, diagnostic, 260, 261
X-ray diffraction, 195
X-ray fluorescence (XRF), 501
X-ray machine, 263, 276
Xylene, 59, 161, 164, 681
Y
Yamate method (microscopy), 197
Yellow fever, 427
Z
Zero adjustment, 564
Zinc chloride, 59
Zinc oxide, 173
Zinc protoporphyrin (ZPP), 501
Zoonotic disease, 425–26