Study Guide Answers

# Fundamentals of Industrial Hygiene

Fifth Edition

National Safety Council®

NSC PRESS

**NATIONAL SAFETY COUNCIL MISSION STATEMENT**
The mission of the National Safety Council is to educate and influence society to adopt safety, health, and environmental policies, practices, and procedures that prevent and mitigate human suffering and economic losses arising from preventable causes.

**COPYRIGHT, WAIVER OF FIRST SALE DOCTRINE**


**DISCLAIMER**
Although the information and recommendations contained in this publication have been compiled from sources believed to be reliable, the National Safety Council makes no guarantee as to, and assumes no responsibility for, the correctness, sufficiency, or completeness of such information or recommendations. Other or additional safety measures may be required under particular circumstances


Printed in the United States of America
06 05 04 03 02 1 2 3 4 5

ISBN: 0-87912-237-4

5C0302 Product Number: 15108-0000

# Contents

# Chapter 1
# Overview of Industrial Hygiene

## ANSWERS—Quiz 1

1. b
2. a
3. a
4. a
5. b
6. b
7. b
8. b
9. a
10. b
11. c
12. c
13. b
14. c
15. b

16. Industrial hygiene is the 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.

17. The groups include the American Conference of Governmental Industrial Hygienists (ACGIH), American Academy of Industrial Hygiene (AAIH), American Board of Industrial Hygiene (ABIH), and American Industrial Hygiene Association (AIHA).

18. Student should name three of the following: 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 facility.

19. 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.

20. Employees are excellent sources of information on work processes and procedures and the hazards of their daily operations. The industrial hygienist benefits from this source of information and often obtains innovative suggestions for controlling hazards.

21. 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.

22. A Health Hazard Evaluation is an on-the-job investigation of reported worker exposures that are carried out in response to a request by either the employer or the employee or employee representatives.

23. 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; and housekeeping.

24. The Canons of Ethical Conduct are as follows: 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. Canon 2: Industrial Hygienists shall counsel affected parties factually regarding potential health risks and precautions necessary to avoid adverse health effects. 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. Canon 4: Industrial Hygienists shall avoid circumstances where a compromise of professional judgment or conflict of interest may arise. Canon 5: Industrial Hygienists shall perform services only in the areas of their competence. Canon 6: Industrial Hygienists shall act responsibly to uphold the integrity of the profession.

25. The four environmental factors or stresses are as follows:

    (1) Chemical hazards 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.
    (2) Physical hazards include excessive levels of nonionizing radiation, ionizing radiation, noise, vibration, and extremes of temperature and pressure.
    (3) Ergonomic hazards 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.
    (4) Biological hazards 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.

## ANSWERS—Quiz 2

1. b
2. b
3. a
4. b
5. a
6. a
7. b
8. c
9. b
10. a
11. c
12. c
13. a
14. b
15. c

16. 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. The typical functions of the safety and health committee include: 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.

17. The key elements to consider are (1) the route of entry of the chemical into the body, (2) how much of the material is required to be in contact with a body cell to produce injury, (3) the probability that the material will be absorbed or come in contact with body cells, (4) the rate of generation of airborne contaminants, (5) the control measures in place, and (6) the total time of contact.

18. 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; and physiological effects (noise-induced hearing loss or aural pain when exposure is severe).

19. The following factors can influence the effect of the noise exposure: variation in individual susceptibility; total energy of the sound; frequency distribution of the sound; total daily duration of

exposure; length of employment in the noise environment; other characteristics of the noise exposure, such as whether it is continuous, intermittent, or made up of a series of impacts.

20. The signs for heat exhaustion include mildly elevated temperature, pallor, weak pulse, dizziness, profuse sweating, and cool, moist skin.

21. Certain radioactive 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.

22. Electric welding arcs and germicidal lamps are the most common strong producers of ultraviolet radiation in industry. The most common exposure to ultraviolet radiation is from direct sunlight.

23. *Barotrauma* is 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 or during decompression.

24. The respiratory system consists of the nose, mouth, upper throat, larynx, trachea, bronchi, lungs, diaphragm, and muscles of the chest. Respiratory hazards can be broken down into two main groups: oxygen deficiency and air that contains harmful or toxic contaminants.

25. Factors that affect the degree of eye injury induced by laser light include the following: (1) pupil size, (2) the ability of the cornea and lens to focus the incident light on the retina, (3) the distance from the source of energy to the retina, (4) the energy and wavelength of the laser, (5) the pigmentation of the eye of the subject, (6) the location on the retina where the light is focused, (7) the divergence of the laser light, and (8) the presence of scattering media in the light path.

26. The relevant data concerning lifting can be classified into task, human, and environmental variables. (1) 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, and working position. (2) Human variables: sex of worker, age of worker, training of worker, physical fitness or conditioning of worker, and body dimensions of the worker. (3) Environmental variables: extremes of temperature, humidity, and air contaminants.

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

## ANSWERS—Case Study

1. The four major U.S. industrial hygiene organizations are the American Conference of Governmental Industrial Hygienists, the American Academy of Industrial Hygiene, the American Board of Industrial Hygiene, and the American Industrial Hygiene Assosiation.

2. The Canons of Ethical Conduct are as follows: 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. Canon 2: Industrial Hygienists shall counsel affected parties factually regarding potential health risks and precautions necessary to avoid adverse health effects. 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. Canon 4: Industrial Hygienists shall avoid circumstances where a compromise of professional judgment or conflict of interest may arise. Canon 5: Industrial Hygienists shall perform services only in the areas of their competence. Canon 6: Industrial

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

3. 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.

4. The student should demonstrate an understanding of what this form is, how it can be consulted for toxicological information, and who might find the information useful.

5. The student should demonstrate an understanding of the various routes of entry for harmful agents: inhalation, skin absorption, and ingestion.

# Chapter 2
# The Lungs

## ANSWERS—Quiz 1

1. b
2. a
3. b
4. a
5. b
6. c
7. a
8. c
9. b
10. a

11. The human respiratory system includes the nose, the pharynx, the larynx, the trachea, the bronchi, and the lungs.

12. Sounds are created as air is forced past the vocal cords, making them vibrate. These vibrations make the sound. Words and other understandable sounds are formed by the tongue and muscles of the mouth.

13. The trachea divides into the right and left main stem bronchi.

14. *Metabolism* is the process through which the body combines oxygen with food substances and thus produces energy.

15. *The AMA Guides* classify respiratory impairment into four classes: none, mild, moderate, and severe.

16. *Bronchitis* is an inflammation of the lining of the bronchial tubes.

17. In a relaxed state, a person breathes in and out 10-14 times a minute, with each breath lasting 4-6 seconds.

18. A pneumothorax is an introduction of air between the pleural layers that would decrease or disrupt the negative atmospheric pressure between the layers; the lung would partially or totally collapse.

19. Carbon dioxide diffuses from tissue cells and tissue fluid into the blood because the concentration of carbon dioxide in tissue cells and fluid is higher than in the blood in capillaries. If there is a pressure difference across a permeable membrane (such as that separating the alveoli from the pulmonary capillaries), gas molecules pass from the high- to low-pressure region until the pressures are equalized.

20. The nose is an external organ lined by an extensive mucous membrane that warms, moistens, and filters inhaled air. It is the organ of smell.

## ANSWERS—Quiz 2

1. a
2. b
3. a
4. b
5. a
6. d

7. b

8. d

9. b

10. The two passageways at the bottom of the throat are the esophagus and the trachea.

11. *Cilia* are hairlike filaments in the nasal cavity and nasopharynx that move in coordinated waves to propel mucus and trapped particles toward the nostrils.

12. The right lung is partially divided into three lobes; the left lung is divided into only two lobes.

13. Two diseases associated with an obstructive ventilatory defect are asthma and chronic obstructive pulmonary disease (COPD).

14. Fine aerosols are potentially more harmful than larger aerosols because only the small (fine) particles are likely to reach the alveoli in great quantities, and because the alveoli are the most important area in the lungs.

15. Particles deposited in the alveoli will be engulfed by macrophages that migrate proximally to the airways and are either expectorated or swallowed or may enter the interstitial tissue.

16. The classification of respiratory impairment is based primarily on spirometric tests of pulmonary function and gas diffusion studies.

17. Vital lung capacity is measured by inhaling as deeply as possible and blowing out as much as possible into a spirometer.

18. Two common forms of pneumoconiosis are silicosis and asbestosis.

19. In diseases associated with an obstructive ventilatory defect, there is reduction of airflow rates and prolongation of expiration. In diseases causing a restrictive ventilatory defect, there is a decreased ability to take a deep breath due to scarred lungs.

20. The three general categories of inhaled contaminants are as follows: (1) aerosols and dusts, which, when deposited in the lungs, may produce tissue reaction and/or disease; (2) toxic gases, which may produce direct tissue injury; and (3) toxic aerosols, which do not affect the lung tissue but are passed from the lung into the bloodstream, where they are carried to other organs or have adverse effects on the oxygen-carrying capacity of the bloodstream.

## ANSWERS—Case Study

1. The inhalation of sufficient quantities of dust, regardless of its chemical composition, can cause a person to choke or cough; it can also accumulate in the lungs. Depending on its chemical composition, dust can cause an allergic or sensitization reaction in the respiratory tract. Depending on both its size and chemical composition, dust can, by physical irritation or chemical action, damage the airway and/or lung.

2. Given adequate recovery time—about 16 hours—after an eight-hour exposure to dust, the healthy lung can cleanse itself.

3. Procedures useful in evaluating impairment of the respiratory system include but are not limited to (1) complete history and physical examination with special reference to cardiopulmonary systems and signs; (2) chest roentgenography (posteroanterior, PA) in full inspiration, lateral, and other procedures as indicated; (3) hematocrit or hemoglobin determination; (4) electrocardiogram, $FEV_1$, FVC, and $D_{co}$; and (5) other tests, such as blood gas and pulmonary exercise studies.

# Chapter 3
# The Skin and Occupational Dermatoses

## ANSWERS—Quiz 1

1. b

2. b

3. a

4. a

5. b
6. c
7. d
8. a
9. b
10. b
11. d
12. They remove the skin's surface lipids and disturb the keratin layer of cells so that cells lose their water-holding capacity.
13. Hair follicles and sweat glands serve as routes for the percutaneous absorption of such drugs as nicotine, nitroglycerine, estrogen, and scopolamine.
14. Nonimmunologic contact urticaria is the most common type of contact urticaria.
15. The skin's two lines of defense against sunlight are an increase in pigmentation and a thickening of the stratum corneum.
16. A hydrofluoric acid burn is characterized by intense pain that is often delayed and progressive deep tissue destruction (necrosis).
17. Temperatures higher than room temperature decrease the breakthrough time of chemicals.
18. Categories of glove standards depend on the type of glove material used, the type of work being done, and the type of hazard encountered.
19. The incidence of allergic contact dermatitis depends on several factors, such as the nature of the materials handled, predisposing factors, and the ability of the physician to accurately use and interpret patch tests. While an irritant usually affects many workers, a sensitizer generally affects few workers. Exceptions to this rule include potent sensitizers, such as poison oak oleoresin, or epoxy resin and components.
20. Patch tests are designed to tell whether people who have previously worked on similar jobs are sensitized to the chemicals with which they have worked. The tests cannot predict whether new workers will become sensitive to certain materials and develop dermatitis. Unless there is active skin disease at the time of placement, medical staff must be careful about restricting people who are not specifically sensitive to the agents involved in a job just because of a history of skin problems. In many cases, the medical staff is limited to informing the individual of the risk. Safety and human resources departments as well as industrial hygienists, supervisors, and others may also play a role in recommending suitable placement on the basis of patch test findings.

## ANSWERS—Quiz 2

1. a
2. b
3. b
4. a
5. a
6. d
7. b
8. b
9. a
10. c
11. a
12. Body heat is lost when sweat evaporates.
13. Most of the causes of occupational skin disease can be classified as chemical, mechanical, physical, biological, or botanical.
14. Phototoxicity and photoallergy are the two types of photosensitivity that are generally recognized.
15. The two main types of glands found in the dermis are sweat glands and sebaceous, or oil, glands.
16. The primary function of environmental control measures in preventing occupational dermatitis

is to reduce the possibility of contact with an offending agent.

17. Four important chemical parameters that should be considered when evaluating glove performance are resistance to swelling, degradation, permeation, and penetration.

18. Clothing worn on the job should not be worn at home because workers' families can develope various types of dermatoses from contact with contaminated clothing. Also, if work clothes are laundered at home, workers' other clothes may become contaminated.

19. One complication of extensive burns is infection, which can endanger the life of the burn victim. In fact, infection is the source of most burn complications. Extensive burns can also result in a loss of body fluid, either plasma or lymph from the blood, that can then cause the victim to go into shock. Finally, the functional, cosmetic, and psychological complications of extensive burns may require the attention of a rehabilitation team.

20. The classifications for the dermatologic reactions to gloves include irritation from occlusion, friction, and maceration, as well as allergy to glove materials and their chemical additives. In this case, wearing gloves can lead to allergic contact dermatitis or allergy to certain natural rubber latex proteins causing contact urticaria. The classifications also cover aggravation of preexisting skin diseases and penetration of chemicals through gloves. Infrequent reactions to endotoxins and ethylene oxide, and to depigmenting chemical constituents of gloves have also been reported.

## ANSWERS—Case Study

1. In addition to more direct contributors, such as the duration and extent of exposure to an agent, indirect, or predisposing factors, could be contributing to increased incidence of skin disease at Healthy Meals. For example, younger, inexperienced workers, such as those hired by Healthy Meals, as well as inadequately trained workers, have a higher prevalence of occupational skin disease than older workers. Skin type also plays a role. Workers with naturally dry skin cannot tolerate the action of solvents and detergents as well as persons with oily skin. Folliculitis and acne induced by cutting oils are common problems for workers with hairy arms and legs. In warm climates, such as that of Florida, occupational skin disease is more common. Workers in these climates wear less clothing and are more likely to come in contact with external irritants. They are also less likely to wear protective clothing if the work area is hot. Excessive perspiration, with resulting skin damage, is more common in warm weather along with exposure to sunlight, poisonous plants, and insects, the effects of which may or may not be job-related. Increased sweating, or hyperhidrosis, can be a predisposing factor in warm or cold climates. It can lead to maceration with softening and resultant separation of skin already irritated by rubbing in adjacent body areas, as happens in the armpit and the groin. Consequently, the skin is predisposed to fungal and bacterial infections. Caustics, soda ash, and slaked lime among other materials become irritants in solution; however, sweating can protect an individual by diluting toxic substances. Gender, hereditary allergy or atopy, personal hygiene, and preexisting skin disease are also predisposing factors.

2. Miliaria, also known as prickly heat or heat rash, is an occupational skin disease related to heat and sweat. It is an inflammatory reaction to retained extravasated sweat that can occur when sweat ducts are obstructed. The lesions may be pinpoint to pinhead-sized papules and vesicles, or blisters, on the chest, back, and submammary, inguinal, and axillary folds. People who sweat profusely while exposed to heat commonly react by developing miliaria. The hot, humid conditions in which employees at Healthy Meals work could have led to miliaria.

3. Food processing, such as that done by Healthy Meals, is among the most hazardous industrial processes for skin disorders. The others include: the use of cutting oils and coolants in machine tool operation, plastics and rubber manufacturing, leather tanning and finishing, metal plating and cleaning, construction, printing, forest products manufacturing, and agriculture. In 1997 the incidence of occupational skin disease in the agricultural sector was 226 cases per 100,000 full-time workers per year, the highest of all industries. Agriculture was followed by manufacturing, which registered 139 cases per 100,000 full-time workers, and services, which registered

61 cases. The transportation/utilities and mining industries had similar rates of incidence, 52 and 51 respectively. Construction and wholesale/retail trade were at the end of the list.

# Chapter 4
# The Ears

## ANSWERS—Quiz 1

1. a
2. a
3. b
4. a
5. b
6. a
7. a
8. a
9. b
10. c
11. b
12. c
13. b

14. Student may provide either the technical or colloquial names for the bones of the ossicular chain. They are the hammer (malleus), anvil (incus), and stirrups (stapes).

15. The ear canal is prone to infection (otitis externa) because of its high skin temperature and humidity. Bacterial and fungal infections occur more readily under circumstances of heavy perspiration or head immersion. Swimmer's ear and dermatitis are common ear canal problems.

16. If a live insect enters the ear canal, drop light mineral oil into the canal to suffocate and quiet the insect until it can be removed by a doctor.

17. Cotton-tipped swabs tend to pack wax into the ear canal, and swabbing stimulates excess production of wax. Normally, the ear canals are self-cleaning.

18. Perforation or rupture of the tympanic membrane can be caused by infection, direct injury (e.g., from a penetrating object) or sudden pressure changes (barotrauma). Examples of the latter would be a blow to the side of the head or large pressure changes associated with air flight, underwater diving, or explosions. Most perforations heal spontaneously and do not require surgical repair, except for those caused by hot substances such as welding splatter.

19. Allergic and infectious conditions that affect the nose and throat can cause swelling, adhesions, or masses in the Eustachian tubes. Failure of the Eustachian tube to ventilate creates a vacuum in the middle ear space, which in turn causes one of two pathological events to occur: It pulls fluid into the middle ear, resulting in a condition called nonsuppurative otitis media, or it pulls the eardrum inward.

20. Disease of the middle ear ossicles can impair hearing in two ways: fixation (the bony chain cannot vibrate or vibrates inefficiently) and interruption (a gap in the chain).

21. An individual should be referred to a physician for further medical evaluation when he or she experiences ear pain; drainage; dizziness; severe persistent tinnitus; sudden, rapidly progressive of fluctuating hearing loss; a feeling of fullness or discomfort in the ear; excessive cerumen accumulation or a foreign body in the ear canal; change of the baseline audiogram of more than 15 dBH; difference in hearing levels of the ears of more than 15 dB at 500, 1,000, and 2,000 Hz or more than 30 dB at 3,000, 4,000, and 6,000 Hz; or average hearing level at 500, 1,000, 2,000, and 3,000 Hz is greater than 25 dB in either ear.

22. Wave motions in the air set up sympathetic vibrations that are transmitted by the eardrum and the three bones in the middle ear to the fluid-filled chamber of the inner ear. In the process, the vibrations of the eardrum are converted to

much smaller but more powerful mechanical vibrations by the ossicles, and finally into fluid vibrations. The wave motion in the fluid is sensed by the nerves of the cochlea, which transmit neural messages to the brain.

## ANSWERS—Quiz 2

1. b
2. a
3. b
4. b
5. a
6. b
7. b
8. c
9. c
10. d
11. c
12. d

13. An abnormal narrowing of the ear canal is called stenosis and may be caused by congenital malformation, bony growth (exostosis), or infection.

14. A variety of ailments can affect the inner ear. For example, damage can result from congenital/developmental defects, systemic diseases (multiple sclerosis, diabetes), infection (mumps or chronic otitis media), exposure to noise or certain toxins (including medications, such as antibiotics or diuretics), circulatory problems (stroke), and trauma (concussion or skull fracture). In the workplace, exposure to excessive vibration, heavy metals, organic solvents, and carbon monoxide may contribute significantly to the hearing loss induced by chronic ambient noise or other medical problems.

15. Meniere's disease affects both parts of the inner hear (hearing and balance) and its cause is unknown. It is characterized by episodic dizziness, often severe, and associated with nausea, vomiting, fluctuating hearing loss that is generally progressive, ringing or hissing noise, and a peculiar sensation of fullness in the involved ear.

16. Acoustic neuroma is a tumor that occurs most commonly in middle-aged persons and affects the eighth cranial nerve. Although not malignant, it can cause disabling symptoms of both hearing loss and vestibular dysfunction. Workers with vertigo or equilibrium problems may not be medically fit for safety-sensitive tasks such as operating motor vehicles or working at heights.

17. Tinnitus is the perception of sound arising in the head. It may be heard only by the affected person (subjective tinnitus) or it may be audible to the examiner also (objective tinnitus). Objective tinnitus is usually a symptom not of disease of the ear but of a tumor or vascular malformation.

18. Audiometric results are recorded on a standard chart called an audiogram. It is a frequency-by-intensity graph on which a person's hearing threshold for pure tones is plotted.

19. The factors that determine the duration and severity of noise-induced hearing loss include sound level, frequency distribution of sound, duration of sound, temporal distribution of sound exposure, type of sound energy, individual differences in tolerance of sound.

20. Research on other effects of noise indicates that it may cause interference with communication, altered performance, annoyance, and physiological responses such as elevated blood pressure and sleep disturbances. Shouting to overcome noise has been observed to lead to chronic laryngitis and vocal cord polyps.

21. When testing hearing by air conduction, headphones are placed over the ears of the test subject. A pure tone signal from the audiometer is presented through the headphones and travels through the ear canal, the middle ear, and into the inner ear, thus allowing evaluation of the entire hearing mechanism, both conductive and sensorineural. Bone conduction audiometry evaluates only the sensorineural hearing mechanism. A bone vibrator is placed on the mastoid bone

behind the outer ear. This sends vibrations directly through the skull bones to the cochlea in the inner ear, bypassing the conductive pathway of the outer and middle ear. Bone conduction testing is considered a diagnostic test and is not performed as part of routine industrial hearing assessments.

## ANSWERS—Case Study

1. The student should demonstrate an understanding of the various causes of hearing loss, paying particular attention to Mr. Sachdev's age, occupation, and the fact that he wears earplugs which may push wax deeper into his ear. The answer might include, but is not limited to, the following: Physical blockage of auditory canals, congenital/developmental defects, infection, exposure to noise or certain toxins, circulatory problems, trauma, exposure to vibration, heavy metals, organic solvents, and carbon monoxide, traumatic damage such as punctured eardrums, drug-induced damage, etc.

2. When testing hearing by air conduction, headphones are placed over the ears of the test subject. A pure tone signal from the audiometer is presented through the headphones and travels through the ear canal, the middle ear, and into the inner ear, thus allowing evaluation of the entire hearing mechanism. Bone conduction audiometry evaluates only the sensorineural hearing mechanism. A bone vibrator is placed on the mastoid bone behind the outer ear. This sends vibrations directly through the skull bones to the cochlea in the inner ear, bypassing the conductive pathway of the outer and middle ear. Bone conduction testing is considered a diagnostic test and is not performed as part of routine hearing assessments, so you will use an air conduction test on Mr. Sachdev.

3. The factors that determine the duration and severity of noise-induced hearing loss include sound level, frequency distribution of sound, duration of sound, temporal distribution of sound exposure, type of sound energy, and individual differences in tolerance of sound.

4. The student should give an adequate description of the hearing process, along the lines of the following: The outer ear funnels and conducts sound vibrations to the eardrum through the ear canal. The eardrum vibrates in response to the sound waves that strike it. This vibratory movement is transmitted to the chain of three tiny bones in the middle ear. These small bones, the ossicles, conduct the sound vibration across the air-filled middle ear cavity to a fluid in the inner ear. The vibration of the ossicles creates waves in the inner ear fluid that stimulate microscopic hair cells. The stimulation of these hair cells generates nerve impulses, which pass along the auditory nerve to the brain for interpretation.

# Chapter 5
# The Eyes

## ANSWERS—Quiz 1

1. b
2. a
3. b
4. a
5. b
6. a
7. b
8. a
9. d
10. a
11. d
12. b
13. c
14. The three layers of tissue surrounding the internal structures of the eyeball are the external fibrous layer, a middle vascular layer, and an inner layer of nerve tissue.
15. The tarsal glands, located in the eyelids, secrete

an oil to lubricate the surfaces of the eyeball and eyelids.

16. The choroid is a darkly pigmented layer of tissue underlying the retina, which contains an extremely rich blood supply that is believed to dissipate the heat resulting from absorbed light energy.

17. The ciliary muscles alter the lens shape to fine-focus the incoming light beam.

18. The two functionally discrete types of light-sensitive cells in the retina are rods and cones.

19. An ophthalmologist is a doctor of medicine who specializes in the comprehensive care of the eye and visual system and is licensed by a state to practice medicine and surgery.

20. A phoropter is used to determine refractive correction (eyeglass prescription) and binocular vision abnormalities. It consists of test lenses and prisms that are added and removed using both objective criteria and subjective responses.

21. Stereoscopic vision gives a perception of depth. There is a slight difference in the images on the two retinas; there is a right-eyed picture on the right retina and a left-eyed picture on the left retina. The two images blend in consciousness and give an impression of depth or solidity.

22. Astigmatism occurs when the curvature of the cornea is irregular so that some rays of light are bent more in one direction than in another; the resulting image is blurred because if one part of the ray is focused, the other part is not.

## ANSWERS—Quiz 2

1. a
2. b
3. a
4. a
5. b
6. c
7. a
8. d
9. a
10. Significant impairment of vision that cannot be improved by corrective lenses is designated as "low vision."
11. The leading causes of existing cases of blindness are (1) glaucoma, (2) macular degeneration, (3) cataracts, (4) atrophy of the optic nerve, (5) diabetic retinopathy, and (6) retinitis pigmentosa.
12. A diopter is a unit of measurement of the refractive or light-bending power of a lens.
13. *Rod monochromatism* is a condition in which people have no cones in their retinas, only rods. These people are truly color blind.
14. Viral eye infections usually produce tearing; bacterial infections cause pus or mucous discharge; and allergic reactions cause itching and occasionally a "stringy" discharge.
15. Cataracts can be associated with industrial exposures to ionizing radiation, ultraviolet radiation, infrared radiation, foreign bodies, and certain chemicals.
16. *Nystagmus* is the involuntary movement of the eyeballs.
17. *Acute keratoconjunctivitis*, an acute inflammation of the cornea and conjunctiva, is commonly known as welder's flash.
18. Only safety eyewear that meets or exceeds the requirements of ANSI standard Z87.1B1989 is approved for full-time use by industrial workers.
19. For safety eyewear, polycarbonate lenses are the most impact-resistant.
20. About 4 percent of the population (95 percent of whom are male) inherits a defect in one of the cone pigments so that the wavelength of maximum absorption is somewhat shifted. People with these color defects are not color "blind," as they do see colors, but rather are color defective in that they perceive certain colors differently

from people with normal cone pigments.

21. An eye-hazard area is an area where the continuous or intermittent work being performed can cause an eye injury to anyone in the area. The concept emphasizes the need for process and environmental controls such as enclosures and radiation-absorbing surfaces, and provides eye protection equipment for workers, neighboring workers, supervisors, and visitors.

## ANSWERS—Case Study

1. Invasion by a foreign body is the most common type of physical injury to the eye.

2. The most common complication with an industrial eye injury is infection, which can cause delayed healing and corneal scarring.

3. In some cases, the speed of small metallic particles creates enough heat to sterilize them, making infection less of a problem. Wood particles, however, do not heat up; if they penetrate the eye, they can cause dangerous infection, which usually causes a marked reduction in vision.

# Chapter 6
# Industrial Toxicology

## ANSWERS—Quiz 1

1. b
2. b
3. b
4. a
5. a
6. b
7. d
8. d
9. c
10. c
11. d
12. The cutaneous absorption rate of some organic chemicals increases when temperature and perspiration increase.

13. The dose-response relationship can be expressed as the product of concentration (C) and duration of exposure (T).

14. Hypersusceptibility is the occurrence of the usual health effects caused by a substance following exposure to air levels below those associated with effects for most individuals.

15. According to NIOSH, a substance should be considered a suspected carinogen if it produces cancers in two or more animal species.

16. If epidemiological data and cases of human exposure are not available for study, the preferred method for determining TLVs® is to use studies of long-term inhalation tests involving several animal species at concentrations both above and below the lowest effect level.

17. Rates of absorption, metabolism, and excretion determine when it is most appropriate to analyze biological samples in relation to duration and time of exposure.

18. Samples of urine, blood, or expired air taken under strictly defined conditions are used to determine Biological Exposure Indices®.

19. Toxicologists define *toxicity* as the ability of a substance to produce an unwanted effect when the substance has reached a sufficient concentration at a certain site in the body. They define *hazard* as the probability that this concentration will occur at that site. Toxicity, along with the chemical and physical properties of a substance, determine the level or degree of hazard.

20. A mutagen is an agent that affects the genetic material of an exposed organism. It may cause cancer, birth defects, or other undesirable effects in later generations. People working with a certain chemical may not be harmed, but their offspring can be. A teratogen, however, affects only the developing fetus. It may be a biologi-

cal, chemical, or physical agent that produces malformations of the fetus without affecting the mother or killing the fetus. This is known as teratogenesis. Unlike the effects of mutagens, the malformations caused by teratogens are not hereditary. Like mutagens, it is difficult to establish specific cause-and-effect relationships between teratogens and the birth defects they can produce.

## ANSWERS—Quiz 2

1. a
2. a
3. a
4. b
5. b
6. d
7. c
8. b
9. a
10. b
11. d
12. The toxicity of a chemical depends on the degree of exposure and absorption.
13. If the skin comes in contact with a toxic substance, either (1) the skin will act as an effective barrier, (2) the substance will react with the skin and cause local irritation or tissue destruction, (3) the substance will produce skin sensitization, or (4) the substance will penetrate the skin to reach the blood vessels under the skin and enter the bloodstream.
14. It is difficult because the lag time between exposure and effect is so severe. Damage caused by mutagens may not show up until the next generation of the exposed organism at the earliest, and may not appear for several generations.
15. The "Hazcom" or "right-to-know" regulation is Hazard Communication Standard, 29 *CFR* 1910.1200, which was enacted by OSHA in 1983 to set standards for worker notification and training for chemicals in the workplace.
16. When two or more hazardous substances that act on the same body organ system are present, primary consideration should be given to their combined effect.
17. If inhaled gases are fat-soluble and are not metabolized, they are cleared from the body primarily through the respiratory system.
18. No, the company can withhold the names of the ingredients, but it must disclose their hazardous properties, if any exist.
19. $LD_{50}$ is the dose of a substance that is expected to kill 50 percent of a defined experimental animal population, as determined from exposure to the substance by any route other than inhalation. Although $LD_{50}$ is the concentration that kills half of the exposed animals, it does not mean the other half are in good health. Generally, $LD_{50}$ units represent the weight of the substance per kilogram of animal body weight, usually milligrams per kilogram. The value should indicate the species of animal used, the route of administration of the substance, the vehicle used to dissolve or suspend the substance, if applicable, and the time period during which the animals were dosed and observed. $LD_0$ is the concentration that produces no deaths in an experimental group and is the highest concentration tolerated in animals. It is rarely used. $LD_{100}$ is the lowest concentration that kills 100 percent of the exposed animals.
20. A substance-specific standard covers the exposure limit of the substance that has been determined to provide a safe, healthful work environment. It identifies the methods for collecting, sampling, and analyzing the substance and the engineering controls necessary for maintaining a safe environment. The standard should suggest appropriate equipment and clothing for safe handling of the substance and emergency procedures in case of an accident. It should also spell out the medical surveillance procedures required to detect illness or injury from overexposure and the signs and labels needed to identify hazardous substances.

## ANSWERS—Case Study

1. TLVs®, or threshold limit values, were developed by the American Conference of Governmental Industrial Hygienists (ACGIH) and are the most widely followed voluntary guides for exposure to airborne contaminants. However, they are not the recommendations of a government agency and, like standards and guidelines developed by OSHA, ACGIH, NIOSH, and others, TLVs® do have drawbacks. Most importantly, they can only serve as guides—not as fine lines between safe and dangerous concentrations of contaminants. Another drawback relates to the difficulty involved with collecting a truly representative breathing zone sample. There are also questions about the extent of absorption of the amount inhaled, as well as problems sampling the air conditions surrounding nonroutine or nonrepetitive work. Under these working conditions, air samples can characterize work operations only on the day the sample is taken. Other drawbacks are the variations in particle size, absorption, and particle solubility. A final disadvantage is that air samples can be accidentally or deliberately contaminated.

2. Biological sampling can be a useful way of assessing a worker's exposure to harmful chemicals; however, it should not be substituted for air sampling. Biological sampling measures the amount of chemical absorbed via any route (lungs, skin, mucosa, etc.), as well as the effects of added stress. For example, an increased work load may result in a higher respiration rate and a higher intake of a contaminant. Biological sampling shows the total exposure—both on and off the job—to harmful chemicals. Ethical considerations prohibit using workers as "integrated air-sampling devices."

3. Nearly every tissue on the body can be sampled and analyzed, providing an indication of the body burden of a substance, the amount of the substance circulating in the blood, or the amount being excreted. Most biological testing is limited to urine or blood sampling, but sometimes samples of hair, nails, feces, or other tissues may be useful. In the case of carbon monoxide and many solvents, analyzing samples of exhaled breath indicates the level of exposure. Analyses of biological samples can include sampling body fluids and tissues and testing them for unchanged substances, such as lead, arsenic, or mercury. In other cases, analyses of body fluids or tissues can target the metabolites of the substance. Another type of analysis involves studying variations in the levels of naturally occurring enzymes or other biochemical substances normally present in body fluids or tissues.

# Chapter 7
# Gases, Vapors, and Solvents

## ANSWERS—Quiz 1

1. b
2. b
3. a
4. b
5. b
6. a
7. b
8. a
9. a
10. b
11. a
12. d
13. The three fundamental states of matter are gases, liquids, and solids.
14. The most commonly used guidelines in the United States are TLVs® (Threshold Limit Values), PELs (Permissible Exposure Limits), and RELs (Recommended Exposure Limits.)
15. A functional group in an organic molecule is a region where reactions can take place.
16. The student needs to name ONE of the following: *Hawley's Condensed Chemical Dictionary; The*

*Merck Index; Clinical Toxicology of Commercial Products;* or *Fire Hazard Properties of Flammable Liquids, Gases, and Vapors.*

17. Cryogenic liquids pose several safety concerns in addition to frostbite from extreme cold. Spills rapidly vaporize, producing a gas that is initially significantly more dense than air, resulting in potential oxygen deficiency hazards in pits, vaults, and enclosed spaces. Liquid nitrogen is the most common cryogenic fluid.

18. For each flammable liquid or gas, there is a minimum concentration of its vapor in air below which propagation of flame does not occur on contact with a source of ignition because the mixture is too lean. There is also a maximum concentration of vapor, in air, above which propagation of flame does not occur because the mixture is too rich. This is its flammable range.

19. A simple asphyxiant exerts no direct action, but acts passively by merely replacing oxygen in the air so that the concentration of oxygen falls below the 18 percent minimum required for life. Chemical asphyxiants react with essential cellular molecules to disrupt the transport or use of oxygen. Chemical asphyxiants may also interfere with the cell's ability to use the oxygen which is delivered.

20. The evaluation procedure, where the industrial hygienist assesses the degree of risk in the workplace, is based on the following factors: the toxicity of the substance, the concentration in the breathing zone, the manner of use, the length of time of the exposure, the controls already in place and their effectiveness, and any special susceptibilities of the employees.

21. Where a solvent system is in use, three distinct possible routes of exposure must be considered. First, if an opportunity exists for skin contact, dermal absorption is important. If the vapor pressure is high, or the temperature is high, inhalation of vapors is important. Finally, one must also consider the possibility of exposure to an aerosolized mist of the solution, in which case there is also exposure to the solutes. Because of the high volume of breathing and the large surface area of the lungs, which are designed for maximum interchange between blood and air in the lungs, inhalation is usually the most important route of exposure.

## ANSWERS—Quiz 2

1. b
2. b
3. a
4. b
5. a
6. a
7. b
8. c
9. c
10. b
11. b
12. a
13. d

14. NTP stands for normal temperature (25 C) and pressure (1 atmosphere).

15. Threshold Limit Values refer to 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 health effects.

16. HF is particularly corrosive to tissue and bone. Pain from a solution stronger than 50 percent is felt within minutes; lower concentrations may not produce pain for hours. Serious tissue damage may result without the person being aware of it. HF burns require immediate action: irrigate the exposed area to flush away as much HF as possible and seek medical attention immediately. Treatment is dependent on the severity of the burns. Mild cases can be managed with magnesium oxide but more severe burns may require infiltration of the affected tissue with calcium gluconate.

17. The common organic solvents can be classified as aliphatic, cyclic, aromatic, halogenated hydro-

carbons, ketones, esters, alcohols, and ethers.

18. The halogens are a group of five elements: fluorine, chlorine, bromine, iodine, and astatine.

19. Methanol and ethanol are the two most important industrial alcohols. Methanol causes several types of injuries, notably impairment of vision and injury of the optic nerve. Ethanol is quickly metabolized in the body and largely converted to carbon dioxide, and is the least toxic of the alcohols. The undesirable effects of ethanol primarily are related to its recreational use, as it acts as a depressant, slowing down the central nervous system.

20. Carbon dioxide, the product of combustion of carbon-based fuels, contributes to the greenhouse effect. Put simply, solar radiation penetrates the atmosphere and is absorbed by the earth; a portion is radiated back into space, and a portion is consumed in life processes and atmospheric chemical reactions, thus setting up a thermal equilibrium. Carbon dioxide absorbs the shorter wavelength energy re-radiated into space; this energy is manifested as heat.

21. In the essay, the student should demonstrate a complete understanding of the dangers posed by organic solvents and solvent vapors, touching upon skin irritations; defatting of the skin; dermatitis; and damage to the liver, kidneys, central nervous system, and peripheral nervous system. The student may mention specific symptoms such as dizziness, disorientation, confusion, euphoria, giddiness, paralysis, convulsions, and cardiac arrest.

## ANSWERS—Case Study

1. Hydrocarbons are those compounds with only carbon and hydrogen atoms.

2. Different classes include: aliphatic hydrocarbons, cyclic hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons, and nitrohydrocarbons.

3. For credit, students should list at least two sources for hydrocarbons. These include: volcanoes, biological decay, biological activity in soils and the oceans, forest or grassland fires, automobiles, and solvents from industrial cleaning and surface-coating processes.

4. In the presence of sunlight, hydrocarbons react with atomic oxygen and ozone to produce aldehydes, acids, oxides of nitrogen and sulfur, and a series of other noxious compounds to form air pollution. The student should provide an answer that discusses the physical effects of air pollution on the human body.

5. In 1987, the industrialized nations met and signed the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol calls for the reduction of use and elimination of the major ozone-depleting chemicals.

6. Should the destruction of ozone by fluorocarbons and other materials prove to be significant, the amount of solar ultraviolet radiation reaching the earth's surface will increase. This would impair agricultural production and increase the incidence of skin cancer.

7. Carbon dioxide contributes to the greenhouse effect. Put simply, solar radiation penetrates the atmosphere and is absorbed by the earth; a portion is radiated back into space, and a portion is consumed in life processes and atmospheric chemical reactions, thus setting up a thermal equilibrium. Carbon dioxide absorbs the shorter wavelength energy re-radiated into space; this energy is then manifested as heat. It has been estimated that an increase of $CO_2$ concentration to 370 ppm from the present value of about 320 ppm would increase the temperature 0.5 C.

8. You should not use respirators as the primary or only means of protection against hazardous chemical vapors because too many factors limit their use. They can be used as emergency or backup protection. Respiratory equipment is limited by leakage around the mask edges, surface contamination, impaired efficiency with use, and need for adequate oxygen. Unless it is correctly used and properly cared for, a respirator may present a greater danger to a person than no protection at all.

# Chapter 8
# Particulates

## ANSWERS—Quiz 1

1. a
2. b
3. a
4. b
5. b
6. a
7. a
8. b
9. b
10. b

11. In the field of industrial hygiene, particulate matter is defined as small (less than 100 micrometers in diameter) pieces of solid materials, liquid droplets, or microbiological organisms.

12. Particles smaller than about 0.001 $\mu$m start to act like gases and thus are not treated as particulate matter.

13. The five primary mechanisms of particle deposition are (1) inertial impaction, (2) interception, (3) sedimentation (settling), (4) electrostatic attraction, and (5) diffusion (Brownian movement).

14. Because long, narrow asbestos fibers can travel through the lung lengthwise, like an arrow, they can penetrate much deeper into the lung than a nonfibrous particle with a diameter equal to the length of the fiber. As a result, asbestos fibers can make it to the alveolar region of the lungs, which results in scarring of the lungs and cancer.

15. Industrial hygienists are concerned with the equivalent aerodynamic diameter (EAD) of a particle rather than its actual diameter.

16. Types of particle sampling that are common in industrial hygiene include air sampling, surface sampling, biological monitoring, and bioassays.

17. Surface sampling is conducted for several reasons:
    (1) surface sampling is used to determine adequacy of housekeeping and engineering controls in minimizing the spread of highly toxic PM
    (2) when working on laboratory fume hoods, it is used to verify that no potentially explosive perchlorate residue is present in the hood, plenum, duct, or fan
    (3) prior to releasing excess equipment for reuse, utilization, sale, or donation, it is appropriate to test for contamination
    (4) when it is necessary to determine what metals are/were used in an area, surface samples can be analyzed for many metals by inductive coupled plasma emission spectroscopy or similar tool
    (5) surface sampling can be used where the contaminant has a high percutaneous toxicity
    (6) it can be used where the surface dust is a major component of the source term for airborne exposure
    (7) following certain types of abatement actions (lead in particular), surface sampling can be used to verify the adequacy of the decontamination and contamination control procedures
    (8) surface sampling can be used whenever working with potentially radioactive PM

18. The inaccuracy of optical methods of asbestos analysis arises from the fact that the analyst counts all fibers that meet the method specifications, not just asbestos fibers. In addition, the limited resolution of optical microscopes means that the narrowest and potentially most toxicologically significant fibers are systematically undercounted.

19. The most common method for differential fiber counting in asbestos sampling is transmission electron microscopy (TEM).

20. The aerosol is passed continuously through the device, illuminated by a light, and the scattering of light at a 90-degree angle by particles in

the aerosol is used to enumerate and size the particles.

21. In most cases, a primary factor in the toxicity of inhaled radiological materials is the specific activity of the radioactive atom. Species with high specific activities emit a lot of ionizing radiation per unit of time and mass, and thus more rapidly affect tissue, causing genetic and somatic cell damage. Also important is the type and energy of the radioactive particle (or photon) emitted when the atom decays.

22. The airborne limits for radioactive particles are termed Derived Air Concentrations (DACs). These limits are back-calculated from the preestablished limit for radiation dose to the lungs and other tissues. Unlike chemical exposure limits, which are usually expressed as eight-hour average exposure limits, the DACs are year-long averages.

## ANSWERS—Quiz 2

1. a

2. b

3. a

4. a

5. a

6. d

7. a

8. d

9. a

10. *Pneumoconiosis* is the accumulation of dust in the lungs and the tissue reaction to its presence.

11. The ceiling limit is a concentration of the chemical agent that is usually intended as an absolute limit, a value never to be exceeded even for a short time.

12. Fibrosis is a type of scarring of the lung tissue, which results in loss of flexibility, difficulty breathing, and in severe cases, damage to the right side of the heart as it tries to compensate for reduced blood oxygenation. Many of the pneumoconioses result in fibrosis.

13. In industrial hygiene there is growing emphasis on using particle size-selective sampling to better characterize the level of exposure to relevant dust rather than total dust.

14. As an improved version of total dust sampling, the ACGIH's Inhalable Particle Mass procedure is applicable for particles that can cause adverse health effects regardless of where they deposit in the respiratory tract.

15. To evaluate dermal exposure, ultraviolet fluorescent powders are added to pesticides or other chemicals that can then be imaged and recorded photographically to show the spread of contamination and problems with the workers' practices.

16. Gravimetric analysis is used most often when sampling for nuisance dust or Particulates Not Otherwise Classified (PNOC).

17. Biological organisms most often of interest to the typical industrial hygienist are limited to bacteria, fungi, and viruses.

18. General area samples are used extensively in asbestos abatement, as well as for sampling airborne bacteria and fungal spores.

19. Radon progeny, or radon daughters, are particulate matter decay products.

20. In many cases multiple exposures do not interact, so each exposure is treated independently. Other exposures are known or assumed to be additive. The more closely the particulate matter-related health effects are, the more appropriate it is to judge them to be additive. The exposures are measured simultaneously, the TWA fraction of the respective exposure limits for each agent are added together, and if the value exceeds 1.0, an overexposure situation is assumed to exist. An additive analysis may even include a mixture of PM, vapors, and even physical agents.

21. When sampling PM in a moving airstream, the airflow in the sampling line must be isokinetic with the airflow in the duct or stack; that is, the

velocity of the air in the duct must be the same as the velocity of air in the sampling tube. The effect of nonisokinetic sampling in a duct or stack can be quite severe. The other potential problem is the use of a sampling tube with sharp bends. The sampling tube must face straight into the airflow and curve slowly to exit from the duct. Any sharp bends will cause particle accumulation at the bend by inertial impaction.

### ANSWERS—Case Study

1. Dermal monitoring is a type of PM monitoring that is appropriate for particles presenting a significant skin absorption hazard, such as pesticides.

2. The pesticides are measured from patches of fabric attached to the clothing of workers. After sampling, the patches are removed and sent to a laboratory for analysis of the pesticide.

# Chapter 9
# Industrial Noise

### ANSWERS—Quiz 1

1. a
2. a
3. b
4. a
5. b
6. a
7. b
8. c
9. b
10. d
11. d
12. Occupational hearing loss is a hearing impairment of one or both ears, partial or complete, that results from one's employment. It can be the result of acoustic trauma or noise-induced hearing loss.
13. The root-mean-square (rms) sound pressure is used to measure the magnitude of a sound wave. Sound pressure is measured in micropascals (μPa), newtons per square meter ($N/m^2$), microbars (μbar), and dynes per square centimeter ($d/cm^2$).
14. Changing the frequency of a sound changes its relative loudness because the human ear is more sensitive to the higher frequencies of sound.
15. A source measurement reflects the characteristics of a particular sound source, while an ambient-noise measurement reflects the characteristics of a sound field of generally unspecified or unknown sources.
16. The three parts are the source that radiates sound energy, the path along which the sound energy travels, and the receiver.
17. The four categories of personal hearing-protective devices are enclosures, aural inserts, superaural protectors, and circumaural protectors.
18. If an employee has experienced a standard threshold shift (STS), a protective device must reduce his or her level of noise exposure to 85 dBA or below.
19. The noise emitted by a source travels outward in all directions. If all of the walls, floor, and ceiling surrounding the source are hard, reflecting surfaces, the sound is reflected again and again. The result is a semireverberant location. Almost all industrial machine installations are found in semireverberant locations. Close to a machine, most of the noise is produced by the machine; close to the walls, the reflected noise may be more powerful. The sound level in semireverberant locations is equal to the sum of the noise radiated directly by the source and the noise reflected off the walls, floor, and ceiling. Applying sound-absorption material to the walls and ceiling can reduce reflected noise, but cannot decrease the noise produced by the source.
20. All job applicants should take preplacement

hearing-threshold tests—not just those who may be assigned to work in noisy areas. These tests are important for two reasons. By screening all applicants, a company is able to establish a baseline hearing threshold for each employee for comparison in the future. A company can also use the results of preplacement tests to protect itself from liability for preexisting hearing loss incurred elsewhere. If an employee with hearing damage is hired and then exposed to hazardous noise levels, the company may be liable for all the employee's hearing loss unless it can prove that the employee was hired with a preexisting condition.

## ANSWERS—Quiz 2

1. a
2. b
3. b
4. b
5. a
6. c
7. a
8. d
9. c
10. a
11. b
12. The effects include the masking of wanted sounds, particularly speech; auditory fatigue; damage to hearing; and annoyance.
13. The threshold of hearing is the weakest sound that can be heard by a person with very good hearing in an extremely quiet location. The threshold of hearing for an average person is a sound pressure of 20 μPa at a reference tone of 1,000 Hz.
14. The upper limit of frequency at which airborne sounds can be heard depends primarily on the condition of a person's hearing and the intensity of the sound.
15. The A-weighted sound level measurement is believed to provide a rating of industrial broadband noises that indicates the harmful effects this noise has on human hearing. It has also been proven to offer reasonably good assessments of speech interference and community disturbance conditions.
16. Earplugs and earmuffs do not reduce or eliminate a noise hazard. If these protective devices fail, the individual wearing them is immediately exposed to the hazard.
17. The five components of an effective industrial audiometric program include medical surveillance, qualified personnel, a suitable test environment, calibrated equipment, and adequate record keeping.
18. According to NIOSH, a standard threshold shift (STS) is a 15 dB loss in either ear at frequencies of 500, 1,000, 2,000, 3,000, 4,000, or 6,000 Hz. The loss is determined by two consecutive tests.
19. Noise is made up of various sound intensities at various frequencies and needs to be broken down into these frequencies for two reasons. First, people react differently to low-frequency and high-frequency noises. For example, at the same sound pressure level, high frequency noise is much more disturbing and is more likely to result in hearing loss. Second, the engineering solutions for reducing or controlling noise are different for low-frequency and high-frequency noises. Generally, high-frequency noise is easier to control.
20. The company must notify the employee within 21 days that he or she was shown to have an STS. The employee must then be fitted with adequate hearing protectors, shown how to use them, and required to wear the protectors. Some employees might be referred for further testing if their tests results are questionable or if they have an ear problem of a medical nature caused or aggravated by wearing hearing protectors. If subsequent audiometric tests show that the STS identified during and earlier test is not persistent, the employee can discontinue wearing hearing protectors if he or she is exposed to a TWA of less than 90 dBA.

## ANSWERS—Case Study

1. Occupational hearing loss is a hearing impairment of one or both ears that results from one's employment. Hearing loss can be partial or complete and can result from acoustic trauma or be noise-induced.

2. Acoustic trauma is damage to the sensorineural areas of the inner ear. It can occur following one or a few exposures to sudden intense acoustic forms of energy resulting from blasts and explosions or by direct trauma to the head or ear. In the case of acoustic trauma, the worker identifies his or her hearing loss with one incident. Unlike acoustic trauma, noise-induced hearing loss is the cumulative permanent loss of hearing that develops over months or years of hazardous noise exposure. It also damages the sensorineural areas of the inner ear. Noise-induced hearing loss generally affects both ears equally in the extent and degree of loss. To determine if an employee has noise-induced hearing loss caused by conditions on the job, a doctor considers: the employee's history of hearing loss, including onset and progress; the employee's occupational history, including type of work and years of employment; the results of the employee's otological exam; and the results of audiological and hearing studies conducted periodically and at preplacement and termination. The doctor must also be able to rule out nonindustrial causes.

3. In identifying the risk factors for occupational hearing loss, it is important to recognize that if the ear is subjected to high levels of noise for a sufficient period of time, some hearing loss will occur. The factors that affect the degree and extent of loss include: the intensity of the noise (the sound pressure level), the type of noise (frequency spectrum), the period of exposure each day (worker's schedule per day), and the total work duration (years of employment). These four factors are referred to as noise exposure factors and are the most important risk factors for occupational hearing loss. Other factors that can contribute to occupational hearing loss are: individual susceptibility, the age of the worker, coexisting hearing loss and ear disease, the character of the surroundings in which the noise is produced, the distance fromthe source, and the position of the ear with respect to sound waves.

4. The risk factors for hearing loss can be aggravated by problems with protective equipment, such as earmuffs. When earmuffs are worn with eye protection equipment, the degree of hearing protection must not be compromised. However, when they are worn over the frames of eye-protective devices, earmuffs are less efficient protection devices. In this case, the amount of reduction in noise attenuation depends on the type of glasses being worn as well as the size and shape of the wearer's head. If a worker must wear eye protection with earmuffs, devices with cable-type temples are recommended because they create the smallest possible opening between the seal of the earmuff and the worker's head.

# Chapter 10
# Ionizing Radiation

## ANSWERS—Quiz 1

1. a
2. b
3. a
4. b
5. a
6. b
7. a
8. c
9. a
10. b
11. d
12. a
13. c
14. d
15. a

16. Background radiation is primarily a result of cosmic rays, which constantly bombard the earth from outer space. It also comes from such sources as soil and building materials.

17. A film badge is a piece of masked photographic film worn as a badge for personal monitoring of radiation exposure to gamma-, x-, and high-energy beta-radiation. It is darkened by penetrating radiation, and radiation exposure can be checked by developing and interpreting the film. The type of masking depends on the type of radiation to be measured.

18. Human exposure to neutrons occurs around reactors, accelerators, and sources designed to produce neutrons. Determination of the extent of damage from neutron exposures must be made by trained people using special equipment. The amount of harm caused by a dose is dependent not only on the number of neutrons absorbed but also on their energy distribution.

19. The term nuclear radiation describes all forms of radiation energy that originate in the nucleus of a radioactive atom.

20. When a beta-particle is slowed down or stopped, secondary x-radiation, known as bremsstrahlung, may be produced. Light metals such as aluminum are preferred for shielding from beta-particles because light metals produce less bremsstrahlung radiation. Plexiglas™ is another shielding material that is effective.

21. A half-value layer is the thickness of a specified substance that, when introduced into the path of a given beam of radiation, reduces the value of the radiation quantity by one-half. It is sometimes expressed in terms of mass per unit area.

22. The effects of irradiation on living systems are studied by looking for effects on the living cells, changes in biochemical reactions, evidence of production of disease, and changes in life or normal growth patterns.

23. The two types of injurious effects of ionizing radiation are the somatic effects (injury to individuals) and the genetic effects (which are passed on to future generations).

24. All matter is composed of atoms, each of which has two basic parts: a heavy core, or nucleus, containing positively charged particles called protons and neutral particles called neutrons; and relatively lightweight, negatively charged particles called electrons, which spin around the nuclear core. Neutrons and protons were once considered basic particles. However, they have been found to be composed of even smaller particles. The illustration provided by the student should look comparable to Figure 10-3, page 262, of the text.

25. X-radiation is commonly thought of as electromagnetic radiation produced by an x-ray machine. High-speed electrons are suddenly slowed down when they strike a target, and they lose energy in the form of x-radiation. X rays penetrate different materials to varying degrees. When the x rays hit the film behind the object, they expose it just as light would. Since bone, muscle, fat, and other tissues all absorb x rays in varying degrees, their image on the film lets you see the distinct structures within the body.

## ANSWERS—Quiz 2

1. a
2. a
3. a
4. b
5. a
6. a
7. b
8. a
9. a
10. b
11. b
12. c
13. b
14. b

15. d

16. Half-life is a means of classifying the rate of decay of radioisotopes according to the time it takes them to lose half of their strength/intensity. The half-life of U-238 is 4.51 billion years.

17. The time between exposure and the first signs of radiation damage is called the latent period. The larger the dose, the shorter the period.

18. The pool of health experience data was obtained from the following sources: early radiation workers; medical personnel who routinely administered radiation for diagnostic and therapeutic purposes; patients who were treated with radiation; a group of workers who painted dials with luminous paints containing radium; studies of Japanese atomic bomb survivors.

19. For external radiation exposure hazards, the basic protection measures are associated with time, distance, and shielding.

20. A safe distance is the distance nonoperating workers must maintain from the radiation source in order to receive no more exposure than that specified in the NCRP Radiation Protection Guides, even if personnel were to remain at that distance continually.

21. Potential avenues of exposure to the public are contaminated air or water, waste materials, or employees unknowingly leaving the place of work with contamination on their persons, clothing, or shoes.

22. A glove box is a type of hood that permits rigid control of conditions when radioactive metals are worked.

23. A radioisotope is a radioactive isotope of an element. It can be produced by placing material in a nuclear reactor and bombarding it with neutrons. Many fission products are radioisotopes. They are sometimes used as tracers or as energy sources for chemical processing, food paste urization, and nuclear batteries.

24. The rapidly dividing cells of a fetus are more susceptible to radiation damage than are mature cells. Women of childbearing age who may be exposed to radiation should be informed of the need to protect the fetus from excessive or unnecessary radiation exposure. Severe defects can result from excessive exposure to radiation.

25. Thermoluminescence detectors (TSDs) are used for radiation exposure monitoring of gamma, x-, and beta-radiation. These dosimeters can be worn by the person as body badges or finger rings. Most commonly they are small chips of lithium fluoride. A major advantage of the TLDs is that for x- and gamma-radiation they require no energy source to operate in exposures of 20 keV and higher. The ionizing radiation energy absorbed by the TLD displaces from their ground state those electrons on the TLD. The electrons are trapped in the metastable state but can be returned to the ground state by heating. When electrons return to the ground state, light is emitted. A TLD readout instrument is used to precisely control heating the chip and measuring the light that is then emitted from it. The amount of light released is related to the absorbed radiation dose and, in turn, to the radiation exposure of the individual.

## ANSWERS—Case Study

1. The term *nuclear radiation* describes all forms of radiation energy that originate in the nucleus of a radioactive atom.

2. Some materials are naturally radioactive. Others can be made radioactive in a nuclear reactor or accelerator.

3. The most commonly encountered types of ionizing radiation are alpha-, beta-, and neutron particles and x- or gamma-electromagnetic radiation. Other types are encountered in specialized fields.

4. The effects on organs or tissues depend on the type and energy of the radiation and their residence time within the body. The effects of irradiation on living systems are studied by looking for effects on the living cells, changes in biochemical reactions, evidence of production of disease, and changes in life or normal growth patterns. The ionization process destroys the capacity of reproduction or division in some cells and causes mutation in others. Types of injuries include dermatitis and cancer.

5. The health data was obtained from early radiation workers, medical personnel who routinely administered radiation for diagnostic and therapeutic purposes, patients who were treated with radiation, a group of workers who painted dials with luminous paints containing radium, and studies of Japanese atomic bomb survivors.

6. Student should demonstrate their understanding of monitoring instruments by briefly describing in a sentence or two how each one works. For full descriptions of these items, please see pages 268-269 of the accompanying text.

7. None of these monitoring instruments is universally applicable.

8. They will need to ascertain the required level of radiation protection and evaluate the problems that might arise by analyzing the radiation work in terms of the following factors: area involved, number of rooms and buildings; number of employees exposed to radiation and in what locations; chemical and physical states of the radioactive material and the nature of its use; incidents that might occur and their possible locations; nonradiation hazards involved; nature of the probable radiation exposure or release of radioactive material; inherent danger of the material; probability of detection of hazardous situation by routine surveys or monitoring; knowledge of current conditions; and possible effects of accidents on operations.

# Chapter 11
# Nonionizing Radiation

## ANSWERS—Quiz 1

1. a

2. b

3. a

4. b

5. a

6. b

7. d

8. b

9. a, d

10. c

11. The polarity and strength of the current keeps alternating between positive and negative, so it is called *alternating current.*

12. In the United States, polarity changes occur 60 times a second.

13. The basic law of electrical engineering, Ohm's law, states that volts equals current times resistance or, by units, volts equals amps times Ohms ($V = I \times R$).

14. The speed of electromagnetic radiation is the same in air and in a vacuum, about 300,000,000 m/s or about 186,000 mi/s.

15. The 2001 TLV® for DC electric fields from 0 Hz to 100 Hz is 25 kV/m as a ceiling limit (a limit that should not be exceeded for any length of time).

16. Artificial cardiac pacemakers can be fooled by ambient electric and magnetic fields.

17. Magnetic fields are controlled using permeable alloy that confines the magnetic flux lines and diverts them.

18. Microwaves are the portion of the radio-frequency spectrum ranging from 300 MHz to 300 GHz.

19. The present emission standard for microwave ovens allows new ovens to leak no more than 1 $mW/cm^2$ when measured at 5 cm, and old ovens to leak no more than 5 $m/cm^2$ when measured at 5 cm.

20. UV-B and UV-C produce two undesirable effects: the skin toughening evident among desert dwellers and skin cancer.

21. Magnetic fields are often measured with loops of conducting wire. The lines of magnetic field passing through the loop induce current flow.

The field can be calculated by measuring the amperes of induced current and dividing that by the circumference of the loop.

22. Electric fields can be measured by inserting a displacement sensor, a pair of flat conductive plates, into the field and measuring the electric potential between the plates. The surveyor must stand away from the detector because the surveyor's body will shield the detector and create a falsely low measurement. Thus, these instruments come with long nonconductive handles.

23. The dose rate (rate at which energy is transferred to tissue) is called the specific absorption rate (SAR), expressed in watts of power deposited per kilogram of tissue (W/kg).

## ANSWERS—Quiz 2

1. a
2. a
3. b
4. a
5. b
6. b, c
7. a
8. a
9. a
10. Optical radiation and laser safety standards use radians rather than degrees as a measure of angle.
11. In optical radiation and laser safety standards, the steradian is used to describe portions of the surface of a sphere.
12. Laser is an acronym for "light amplification by stimulated emission of radiation."
13. The potential health effects from lasers are thermal burns, photochemical injuries, and retinal damage. The other hazards of laser use, excluding weapons, are electricity and fire.
14. The units of illuminance are the lux and the footcandle.
15. It is generally agreed that radiation is likely to be found at frequencies above 300 MHz.
16. An object absorbs the most radiation energy if it is about 40 percent of the wavelength and not well grounded, or when it is about 20 percent of the wavelength and well grounded.
17. Radiofrequency standards rely on another interval, the thermal equilibrium of the target organs (the eyes and testes), which is assumed to be six minutes.
18. The Swedish MPR standards are emission standards, rather than exposure standards, for video display terminals (or video display units).
19. A Faraday cage is a grounded enclosure made of continuously bonded conductors. An object inside is protected from electric fields and radiation on the outside.
20. Lasers are hazardous to eyes because they can deposit damaging amounts of energy into the eye well before the aversion reflex (blinking or looking away) ends the exposure.
21. OSHA's original regulation was struck down by the Occupational Safety and Health Review Commission in 1981, but the *UAW, Brock v. General Dynamics Land Systems Division* decision allows OSHA to apply state-of-the-art standards developed by others when OSHA has no standard of its own. So OSHA can enforce ANSI/IEEE C95.1-1991.
22. Lasers work by pumping the electrons in a suitable material, the lasing medium, with strong energy and directing some of that energy out in the form of a beam of radiation.
23. Visible and IR-A lasers produce retinal damage by a mechanism unique to lasers. The highly focused beam generates a steam bubble near the retina that pops, sending shock waves into the retinal tissue that produce thermo-acoustic tissue damage.

## ANSWERS—Case Study

1. The first laser pointers were helium-neon (Class

2 lasers) emitting at 632 nm, but they were delicate because of the glass envelope of the He-Ne laser.

2. Diode lasers (Class 3a), emitting at 670 nm, replaced He-Ne lasers because they are more rugged and compact. Newer diode pointers emitting at 635 nm are now available.

3. The classes of lasers are a series of defined steps as the output of the laser increases from Class 1 (so low-powered as to be intrinsically safe) through Class 4 (very dangerous). Class 2 lasers are visible light lasers that could produce excessive exposures if viewed for more than the 0.25s response time to the average reflexes. Class 3 moderate-power lasers warrant more precautions. The old He-Ne pointers bore a caution label; the original diode pointers bear danger labels.

# Chapter 12
# Thermal Stress

## ANSWERS—Quiz 1

1. b
2. a
3. a
4. b
5. a
6. c
7. c
8. a
9. c
10. d
11. b
12. The three factors that influence the degree of thermal stress felt by a worker are the climatic conditions of the environment, work demands, and clothing.
13. Increased metabolism results in increased rates of heat gain because the conversion from chemical energy to kinetic energy is inefficient.
14. The equation for local heat storage is: $S_{local} = K + D$ where $K$ is conductive heat transfer between the skin and an object and $D$ is the rate of heat transfer to or from the local area by conduction through local tissue and by the heat supplied or removed via local blood flow.
15. If heat stress is episodic, it is assessed in terms of safe exposure times for a given level of heat stress.
16. Three ways of controlling diffuse sources of radiant heat include shielding, insulating surfaces to reduce surface temperature, and decreasing a surface's emissivity.
17. Two physiological responses to cold stress are shivering and reduced blood circulation through the skin.
18. When workers are at risk for cold stress, the general controls that should be implemented include training programs, hygiene practices, and medical surveillance.
19. The skin is the site of heat exchange with the environment. The heat generated by muscular work warms the tissues deep inside the body, generally resulting in an increase in the body's core temperature. Blood circulating through the core picks up heat energy and is then directed to the skin where it is cooled through a process called convection. Convection is the exchange of heat between the skin and the surrounding air. If the surrounding air is cooler than the skin, heat flows from the body and it is cooled. The skin also cools the body by producing sweat, which removes heat energy from the skin's surface as it evaporates. As people become acclimated to heat stress, they sweat more and increase their body's ability to cool itself.
20. Hypothermia is one example of a systemic hazard associated with cold stress. It has many causes, including excessive exposure, exhaustion, and dehydration. Hypothermia can also

affect those people who have a subnormal tolerance, either genetic or acquired, for cold stress. It can also follow drug and alcohol abuse. As hypothermia progresses, the central nervous system becomes more and more depressed. This process results in the signs and symptoms of the disorder: slurred speech, unconsciousness, and fatigue. Fatigue causes the metabolic rate to diminish and blood flow to the skin to decrease, making the skin and underlying tissues more susceptible to local cold injury and increasing the risk of severe hypothermia. First aid for hypothermia includes moving the victim to a warm area and removing any wet clothing; offering modest external warming with blankets, heat packs, etc.; providing warm, sweet fluids to the victim if he or she is conscious; and transporting the victim to a hospital.

## ANSWERS—Quiz 2

1. a
2. a
3. b
4. b
5. a
6. b
7. d
8. d
9. a
10. c
11. b
12. The general equation for thermal balance is: $S = (M + W) + R + C + K + (C_{resp} + E_{resp}) + E$ where $S$ is heat storage rate, $M$ is metabolic rate, $W$ is external work rate, $R$ is radiant heat exchange rate, $C$ is convective heat exchange rate, $K$ is conductive heat exchange rate, $C_{resp}$ is rate of convective heat exchange by respiration, $E_{resp}$ rate of evaporative heat loss by respiration, and $E$ is rate of evaporative heat loss.
13. The three major characteristics of clothing that affect thermal balance are insulation, permeability, and ventilation.
14. The physiological adaptations to thermal stress are increased body temperature, heart rate, and sweating.
15. The four environmental factors central to evaluating heat stress are air temperature, humidity, air speed, and the average temperature of solid surroundings.
16. There are four main topics that should be covered during periodic heat-stress training sessions: describing what heat stress is, recognizing and providing first aid for heat-related disorders, explaining heat stress hygiene practices, and providing an overview of heat stress policy and guidelines.
17. When temperatures fall below 16 C (61 F), steps should be taken to implement workplace monitoring.
18. Physiological demands are modest and productivity greatest in the comfort zone of the thermal stress continuum.
19. The following four questions can be asked in order to determine whether workplace conditions should be evaluated for heat stress: (1) The first question addresses environmental and working conditions: Is the environment recognized as being hot, are the work demands high, or is protective equipment required? (2) The second question examines worker behavior: Are worker behaviors indicative of attempts to reduce heat stress, is morale low or absenteeism high, or are people making mistakes or getting hurt? (3) The third and fourth questions relate to medical issues and trends seen in workers over time. The third question is: Do medical records show a pattern of fatigue, weakness, headache, rashes, or high body temperature? (4) The fourth question covers high body temperature, heart rate, and sweat losses in samples of workers. If the answer to any of these questions is "yes," an evaluation probably needs to be conducted.
20. Engineering controls reduce or contain a hazard. In terms of heat stress, engineering controls are aimed at reducing physical work demands,

reducing external heat gain from the air and hot surfaces, and enhancing external heat loss by increasing sweat evaporation and decreasing air temperature. Some examples of engineering controls include using dilution ventilation and active cooling to reduce air temperature and using fans to increase air movement.

Administrative controls change the way that work is performed in order to limit exposures or risks. Administrative controls for heat stress focus on limiting exposures so that increases in heart rate and core temperature do not exceed accepted limits. Pacing work, sharing work, and adjusting schedules to accommodate for heat exposure are all examples of administrative controls.

## ANSWERS—Case Study

1. Heat stress in the workplace can be recognized in terms of workplace risk factors and in terms of the effects it has on workers. Three workplace risk factors for heat stress are traditionally recognized: hot environments, high work demands, and protective clothing requirements. In essence, if the workplace is generally considered hot, based on the subjective judgment of workers and supervisors, then heat stress may be a concern. If the demands for external work are high, heat stress may be a factor in environments that are considered comfortable by casual observers or others not exerting themselves in the environment. Lightweight, loose-fitting clothing is the ensemble of choice for potential exposures to heat stress. In some cases, however, protective clothing may decrease permeability and ventilation and increase insulation. The added weight of personal protective clothing may increase the metabolic heat load and, as a result, the level of heat stress. Workers loading and unloading materials could be exposed to a hot outside environment and high work demands. Workers asked to retrieve materials from outside the facility are susceptible to heat stress for the same reasons. If both sets of employees require protective clothing to do their jobs, they are also likely candidates for heat stress.

   Heat stress can also be recognized by observing workers' behavior. Workers often do things that reduce their exposure to heat. For example, they may adjust their clothing to increase the effects of evaporation, they may work at a slower pace, they may take short breaks to lower their metabolic rates, or they may take short cuts in work methods. Workers may also seem more irritable, have low morale, and be absent more often. When heat stress is a concern the number of errors made by workers tends to increase, machines break down more often, unsafe behavior is seen more frequently, and accidental injuries increase.

2. In extreme cases, heat stress results in heat-related disorders. Some common heat stress disorders include heat rash, heat exhaustion, and dehydration. Other important heat-related disorders are heat stroke, heat syncope, and heat cramps. Heat stroke is the most serious heat-related disorder, while heat exhaustion is the most common. Dehydration is a precursor to heat exhaustion, but it is usually not noticed or reported by employees. Even if a specific heat-related disorder is not mentioned in a worker's medical records, heat stress may have affected the worker in the form of faintness, weakness, nausea, cramps, headaches, and skin rashes. A worker suffering from heat stress may have a high temperature, or the worker's urine samples may have a high specific gravity caused by dehydration.

# Chapter 13 Ergonomics

## ANSWERS—Quiz 1

1. a
2. a
3. b
4. a
5. a
6. b
7. c
8. a
9. c

10. c

11. c

12. People perform widely differing tasks in daily work situations. These tasks must be matched with human capabilities to avoid underloading, in which human capabilities are not sufficiently used, as well as overloading, which may cause the employee to break down and suffer reduced performance capability or even permanent damage.

13. *Affordance* is the property of an environment that has certain value to the human. (The student will most likely provide the following example from the book, although any reasonable example will be satisfactory.) An example is a stairway that affords passage for a person who can walk but not for a person confined to a wheelchair. Thus, passage is a property of the stairway, but its affordance value is specific to the user. Accordingly, ergonomics provides affordances.

14. The time passing from the appearance of a proximal stimulus to the beginning of an effector action is called *reaction time*. The additional time to perform an appropriate movement is called *motion* or *movement time*. Motion time added to reaction time results in the *response time*.

15. An individual's capacity for work is usually determined by the limits of his or her respiratory and cardiovascular systems to deliver oxygen to the working muscles and by the limits of the metabolic system to use chemically stored energy to do muscular work.

16. The simplest technique for heart-rate assessment is to palpate an artery, often in the wrist. The measurer counts the number of heartbeats over a given period of time—such as 15 seconds—and then calculates the average heart rate per minute.

17. Anthropometry literally means measuring the human, traditionally in metric units of heights, breadths, depths, and distances—all straight line, point-to-point measurements between landmarks on the body and/or reference surfaces. Also, curvatures and circumferences following contours are measured, as is weight. In one standard posture, the subject is required to stand erect (heels together; buttocks, shoulder blades, and back of head touching the wall) with arms vertical and fingers straight. The second posture is employed when measurements are taken on a seated subject.

18. Assessment of human muscle strength is a biomechanical procedure. This assessment uses Newton's Second and Third Laws, which state that force is proportional to mass times acceleration, and that each action is opposed by an equivalent reaction. Since human muscle strength currently is not measured at the muscle *in vivo* and *in situ*, human strength is described by the amount of force or torque applied to an external measuring instrument—which is the kind of data that the engineer needs to design tools and equipment.

19. Fatigue is operationally defined as a reduced muscular ability to continue an existing effort. Anaerobic metabolism—which plays an increasing role as the energetic work demands exceed about half the person's maximal oxygen uptake—results in accumulations of potassium and lactic acid, believed to be the primary reasons for muscle fatigue. Avoid fatigue by allowing short bursts of dynamic work and avoiding long periods of static effort. Keep energetic work and muscle demands low. Encourage taking many short rest pauses; this is better than taking a few long breaks.

20. The student must show a general understanding of the guidelines that would enable a worker to perform his task safely and efficiently. These might include:
    - If people must move material, make sure the movement is predominantly in the horizontal plane. Push and pull, rather than lift or lower, and avoid severe bending of the body.
    - If people must lift or lower material, let them do so between knuckle height and shoulder height. Lifting and lowering below knuckle height or above shoulder height are most likely to result in overexertion injuries.
    - If lifting and lowering must be done by people, make sure these activities occur close to and in front of the body. If the worker must bend forward or, worse, twist the body sideways, overexertion injuries are most likely.
    - If people must move material, make sure the material is light, compact, and safe to grasp. A

light object will strain the spinal column and body tissues less than heavy objects. Compact material can be held more closely to the body than a bulky object. A solid object with good handles is more safely held and more easily moved than pliable material.
- If people must handle material, make sure it does not have sharp edges, corners, or pinch points.
- If material is delivered in bins or containers, make sure it can be easily removed from them, particularly that the operator does not have to "dive" into the container to reach the material.
- People tend to revert to previous habits and customs if practices to replace previous ones are not reinforced and refreshed periodically.
- Emergency situations, the unusual case, the sudden quick movement, increased body weight or impaired physical well-being may overly strain the body, since training usually does not include these conditions.
- If the job requirements are stressful, "doctoring the system" through behavioral modification will not eliminate the inherent risk. Designing a safe job is basically better than training people to behave safely in an unsafe job.

## ANSWERS—Quiz 2

1. a
2. b
3. b
4. b
5. a
6. d
7. a
8. b
9. a
10. d
11. a
12. Kroemer's seven keys for safe and efficient material handling are as follows: Facility Layout, Job Design, Equipment, People, Training Material Handlers, Screening Material Handlers, and Ergonomic Design of Workplace and Work Task.
13. Biomechanical and physiological research has shown that the leg muscles used in this lift method do not always have the needed strength. Also, awkward and stressful postures may be assumed if one tries to enforce this technique under unsuitable circumstances. Hence, the straight-back/bent-knees action evolved into the kinetic lift, in which the back is kept mostly straight while the knees are unbent, but feet, chin, arm, hand, and torso positions are prescribed. Other variants include the freestyle lift and the stoop lift. Overall, the student should have an understanding that there is no single lifting method that is best for all situations.
14. The equation is used for calculating the Recommended Weight Limit. LC is the Load Constant, HM represents the Horizontal Multiplier, VM is the Vertical Multiplier, DM is the Distance Multiplier, AM is the Asymmetry Multiplier, FM is the Frequency Multiplier, and CM is the Coupling Multiplier.
15. The student should mention the philosophy behind wearing belts: When humans prepare to lift or lower a load, they instinctively develop intra-abdominal pressure within the trunk cavity. This pressure is believed to help support the curvature of the spine during the lifting or lowering effort. An external belt around the abdominal region might help to maintain the internal pressure because it makes the walls of the pressure column stiffen. However, studies do not support or condemn the wearing of a belt in industrial jobs and the use of lifting belts for professional material handling does not seem to be an effective way of preventing overexertion injuries.
16. The five general rules that govern space design are (1) Plan the ideal, then the practical. (2) Plan the whole, then the detail. (3) Plan the work process and the equipment to fit the human. (4) Plan the workplace layout around the process and the equipment. (5) Use mockups to evaluate alternative solutions and to check the final design.
17. Complaints related to posture (musculoskeletal

pain and discomfort) and vision (eye strain and fatigue) are, by far, the most frequent health problems voiced by computer operators. Improperly designed workstations, ill-selected furniture, and poorly arranged equipment are the principal causes of postural problems.

18. Repetitiveness and forcefulness of tasks as well as static muscle tension can contribute to CTDs.

19. A red signal light shall be used to alert an operator that the system or any portion of the system is inoperative or that a successful mission is not possible until appropriate corrective or override action is taken. A flashing red signal light is used to denote emergency conditions that require immediate operator action or to avert impending personnel injury, equipment damage, or both. A yellow signal light shall be used to advise an operator that a marginal condition exists. Yellow shall also be used to alert the operator to situations for which caution, rechecking, or unexpected delay is necessary. A green signal shall indicate that the monitored equipment is in satisfactory condition. A white signal light shall be used to indicate system conditions that do not have right or wrong implications, such as alternative functions or transitory conditions. A blue signal light may be used as an advisory, but common use of blue should be avoided.

20. The student needs to demonstrate an understanding of the range and scope of cumulative trauma disorders. Although specific examples of trauma will vary by student, most will touch upon these body components: soft tissues (tendons, bursa, ligaments, etc.), nerves, blood vessels, joints, muscles, etc.

## ANSWERS—Case Study

1. Writer's cramp is another name for carpal tunnel syndrome. It is the result of repetitive pressure on the median nerve in the carpal tunnel of the wrist. It is trigged by rapid, often repeated finger movements and wrist deviations; in this case, it is probably caused by typing or keying in data. Work behavior should be modified to allow employees to perform alternate tasks to avoid so much time on the computer.

2. Until recently, it was believed that an upright trunk was part of a healthy posture. This idea had been used to design office chairs and other furniture. However, today there are no compelling physiological or orthopedic reasons to make people stand or sit straight. This posture is impractical for working since employees move about instead of standing stiff and still. Maintaining any body position remains unpleasant after a while.

3. The free-flowing motion design idea has the following basic tenants:
   - Allow the user to freely move in and with the chair and to halt at will in a variety of sitting postures, each of which is supported by the chair, and to get up and move about.
   - Make it easy for the user to adjust the chair and other furniture, especially keyboard and display, to the changing motions and postures.
   - Design for a variety of user sizes and user preferences.
   - Consider that new technologies develop quickly and should be usable at workstations.

4. Visual interface, manipulation, and body support are the links between a person and a task.

# Chapter 14
# Biological Hazards

## ANSWERS—Quiz 1

1. a
2. b
3. b
4. a
5. a
6. a
7. a, b
8. a
9. c, d
10. c

11. The appearance of a virus capable of destroying the human immune system (HIV) in the 1980s, coupled with the high incidence of occupationally acquired hepatitis B virus infection among health care workers, prompted OSHA to establish a standard that mandates protection of workers from occupational exposure to bloodborne pathogens.

12. *Infection* is an invasion of the body by pathogenic microorganisms and the reaction of the tissues to their presence and to the toxins generated by them.

13. In addition to research, medical, and industrial facilities involving laboratory animals, there is a wide range of occupations in which workers are exposed to animal-related allergens and to infectious agents or their toxins. Agricultural workers, veterinarians, workers in zoos and museums, taxidermists, and workers in animal product-processing facilities are all at risk.

14. Controls for the zoonotic diseases considered to be a hazard for agricultural workers include awareness of specific hazards, use of personal protective equipment, preventive veterinary care, worker education, and medical monitoring or prophylactic therapy, where appropriate.

15. The biosafety guidelines most commonly used in the United States for containment of biohazardous agents in the workplace are those recommended by the Centers for Disease Control and Prevention (CDC), the National Institutes of Health (NIH), and the National Research Council (NRC).

16. One of the most critical workplace controls to minimize exposure to HIV, HBV, and HCV is the reduction of sharps-related incidents.

17. The infection control concept of universal precaution is that all human blood and certain human body fluids are to be treated as if known to be infectious for HIV, HBV, HCV, and other bloodborne pathogens.

18. The components of an epidemiological investigation of any disease outbreak (natural or artificial) are (1) documentation of who is affected; (2) identification of possible sources and routes of exposure; (3) recording of signs and symptoms of disease; and (4) rapid identification of the causative agent.

19. Health effects consistent with endotoxin exposure include fatigue, malaise, cough, chest tightness, and acute airflow obstruction.

20. Organic dust toxic syndrome appears to result from inhaling particles and toxins produced by microorganisms.

21. Infectious airborne particles can be generated not only from aerosolized liquids but also from lyophilized cultures, dried bacterial colonies, dried material on stoppers and caps of culture tubes and bottles, dried exudates, fungal and actinomycete spores released when cultures are opened or contaminated material is disturbed, and dusts from animals.

22. Primary containment, or protection of workers and the immediate work environment, is achieved through the use of good work practices and appropriate safety equipment. Effective vaccines also decrease worker risk.

23. Secondary containment, or protection of personnel in the immediate area outside the laboratory and the community (environment external to the workplace), is attained by using adequately designed, constructed, and maintained facilities and operational practices.

## ANSWERS—Quiz 2

1. a
2. b
3. b
4. a
5. a
6. c
7. d
8. b
9. c
10. a, d

11. Microorganisms are a diverse group of microscopic organisms that includes bacteria, fungi, algae, protozoa, viruses, and prions.

12. Exogenous infections are infections from microorganisms not normally found in or on the human body, but which gain entrance from the environment.

13. The principal modes of transmission for infectious microorganisms and other biological materials include contact transmission (direct or indirect), vector-borne transmission, and airborne transmission.

14. Vector-borne infection results when a causative agent is transmitted to a host mechanically or biologically by a living vector (such as a mosquito or tick) through a bite, directly through the skin in rare cases, or by mechanical means.

15. Foremost among the infectious hazards for women who are pregnant or intend to become pregnant is the potential for congenital infection of the fetus, due to exposure to cytomegalovirus (CMV), rubella, hepatitis B virus (HBV), herpes simplex virus, varicella virus, syphilis, or toxoplasmosis.

16. The conditions are interrelated factors that include route of entry, dose, viability, virulence, mode of transmission, and host susceptibility.

17. The most frequently used disinfectants in the workplace include sodium hypochlorite (household bleach), isopropyl or ethyl alcohol, iodophors (Wescodyne), and phenolics (Lysol and amphyl).

18. Hepatitis C virus is transmitted primarily through large and repeated direct percutaneous exposure to blood.

19. Much of the current increase in cases of tuberculosis has been attributed to HIV-infected people, particularly in Africa and Southeast Asia.

20. Tuberculosis is usually transmitted by the inhalation of infectious droplet nuclei suspended in the air, from coughing, sneezing, singing, or talking.

21. Large water supplies have not been considered attractive targets for bioterrorists due to the large amount of an agent that would be required and the water purification procedures used in most U.S. cities.

22. Typical indoor sources of biological agents that can cause adverse health effects are (1) people, who shed bacteria and viruses; (2) building materials, furnishings, and ventilation system components that provide a suitable environment for organism survival and growth; (3) accumulations of biological materials on indoor surfaces, and (4) animals that shed allergens.

23. Modern demographic and ecologic conditions that favor the spread of infectious diseases include rapid population growth; increasing poverty and urban migration; more frequent movement across international boundaries by tourists, workers, immigrants, and refugees; alterations in habitats of animals and arthropods that transmit disease; increasing numbers of persons with impaired host defenses; and changes in the way food is processed and distributed.

24. Biosafety program components usually include program support, a biosafety officer or specialist, an institutional biosafety committee (IBC), a biosafety manual of written policies and procedures, an occupational health program for relevant employees, and employee training or information communication.

25. Key elements of an effective response plan to a bioterrorism attack include prompt recognition of the incident, staff and facility protection, decontamination and triage of potentially exposed persons, medical therapy, and coordination with external emergency response and public health agencies.

## ANSWERS—Case Study

1. Many investigations of problem buildings are based on the development and testing of hypotheses, carefully formulated, logical answers or explanations. Investigators combine available environmental, epidemiological, medical, and toxicological evidence to develop hypotheses, then devise ways to check these theories to determine which are consistent with available information.

2. There is little formal regulation in this area, and

few guidelines are based on health criteria or are enforceable. Evaluating indoor environmental quality can be a challenging endeavor. Before measuring air concentrations for biological agents, investigators are encouraged first to exhaust other approaches (such as medical evaluation of affected individuals and identification of their illnesses) as well as analysis and correction of deficiencies in building design, maintenance, and operation.

# Chapter 15 Evaluation

## ANSWERS—Quiz 1

1. b
2. b
3. b
4. a
5. b
6. b
7. d
8. c
9. d
10. a
11. b
12. Required by OSHA's Hazard Communication Standard, 29 *CFR* 1910.1200, chemical inventories are used to anticipate possible hazards and to ensure these risks are communicated to employers and employees before they are encountered in the workplace.
13. Process safety management is a systematic approach to evaluating an entire process for the purpose of preventing unwanted releases of hazardous chemicals into locations that could expose employees and others to serious hazards.
14. The three categories of biological monitoring are (1) measurement of the contaminant, (2) measurement of a metabolite of the chemical, and (3) measurement of enzymes or functions that reflect harm caused by hazardous exposure.
15. The employer must either provide alternative work in an area where there is not risk of exposure or allow the worker to stay home and receive full compensation during the treatment period.
16. Accuracy concerns the relationship between a measured value and the true value. For a measurement to be accurate, it must be close to the true value.
17. OSHA distinguishes between full-period, continuous single samples; full-period consecutive samples; and grab samples.
18. When existing documentation does not show that exposure levels were constant, any work time for which no samples were collected must be considered as unexposed time, and a zero is factored into any calculation of the time-weighted average (TWA).
19. The first step toward identifying a potential hazard is to examine the raw materials being used, including any known impurities, and the potential of these materials to do harm. The next consideration is how these materials are modified through intermediate steps. Finally, the finished products or by-products should be evaluated under normal conditions and under anticipated emergency conditions. The questions that should be asked during the evaluation procedure include: what are the raw materials, what is produced, what intermediate products are formed in the process, and what by-products may be released. Questions about usual cleaning and maintenance procedures and hazardous waste production and disposal should also be asked. The industrial hygienist should use these questions to organize the information gathered during the evaluation.
20. To ensure accuracy and precision when sampling, several guidelines should be followed. First, the manufacturer's information for direct-reading instruments should be obtained whenever possible. It should state the accuracy and precision of the method to be used. A calibration schedule

should be established and documented for all equipment used in the sampling process. The *NIOSH Manual of Analytical Methods* should be consulted for accuracy and precision of the methods chosen. When results of the sampling are reported, the NIOSH sampling method should be noted. Finally, only laboratories that participate in industrial hygiene quality control programs should be used to analyze the samples.

## ANSWERS—Quiz 2

1. b
2. a
3. a
4. b
5. a
6. b
7. d
8. d
9. a
10. c
11. d
12. The unequal distribution of risks means being aware that some populations of workers are more likely to have a higher risk of disease and injury in the workplace.
13. Workers should be asked about the content of the their jobs, how they spend their time, if any exposures of concern exist, and if they have noticed any health symptoms, especially those related to contact with chemical products or processes.
14. The increased risk of lung cancer that results from smoking and asbestos exposure is an example of a synergistic or additive effect.
15. The two factors that must be considered are air movement patterns and differences in work habits.
16. The number of samples that needs to be collected depends on the purpose of the sampling, the number of different tasks a worker performs in a given day, and the variability inherent in the contamination generation process.
17. The formula for calculating the TWA for an eight-hour workday is: $C_1T_1 + C_2T_2 + C_NT_N$ / 8 hours, where *C* is the concentration of the contaminant and *T* is the time period during which this concentration was measured.
18. If published standards or guidelines do not exist, industrial hygienists can refer to internal standards developed by the manufacturer, reports published in industry literature, health surveys among those exposed on the job, or animal toxicology data.
19. Since most airborne concentrations fluctuate over time, only extensive, continuous area sampling can provide information about changes in concentration levels in a given location. In-depth area monitoring is not done routinely because it is a lengthy process and requires large amounts of equipment. Although this equipment can be made rugged and reliable, often this is not the case. Leaving the equipment unattended for hours or days without the supervision of a trained technician could result in unreliable data collection during an important step in a process. In addition, area sampling may underestimate an employee's exposure if he or she works close to a process, but the measurement probe or collection device is located away from the point of exposure.
20. The first advantage of the worst-case strategy is that it is designed to solve a problem. By measuring the concentration of the chemical thought to have caused the health symptoms, the industrial hygienist helps identify the source, improve the controls, and correct the problem. Second, the results teach employees valuable lessons about indicators of equipment malfunction, the warning signs of overexposure, and the impact of work practices on the levels of airborne contaminants. Finally, by evaluating the worst case during the longest exposure time to the highest expected concentration and by comparing the results to relevant PELs, STELs, TLVs®, and RELs, the industrial hygienist is able to make assumptions about shorter-term, lower-level exposures.

## ANSWERS—Case Study

1. Typical-day sampling is one approach to air sampling, but it is not as easy as it sounds. Daily variations may make typical exposure difficult to define and measure. The managers and employees being monitored may take extra precautions when they know they are being observed. In addition, concerns about being "sampled" may lead companies to present their best face by adding ventilation or opening doors and windows that are usually closed. Following the typical-day method, preliminary air sampling is usually done on the day shift, when supervision is better, shipping doors are more likely to be open, and the timer for the ventilation system is on the occupied setting. Since both the typical-day and the worst-case scenario methods have drawbacks when used independently, a good sampling strategy makes use of both methods. Fingston Labs should probably incorporate some typical-day sampling into its hazard evaluation process.

2. Biological monitoring is one way of comparing exposure to dose; however, it measures exposure only after it occurs, and after the contaminant has affected the body in some way. It must not be used as the sole control measure, as is sometimes the case when employers want to spare the cost of a more comprehensive, expensive monitoring program. Biological monitoring and medical surveillance should not replace environmental, or area, sampling or personal sampling. Instead, a combination of all four types of monitoring should be used.

3. When it comes to deciding which employees to sample, it is important to begin by determining which employee is the most highly exposed, especially if the initial results of monitoring suggest the possibility of excessive exposure. One way of doing this is to observe the point of release of the contaminant and select the employee who is closest to it. This determination can be complicated by other factors, such as air movement. For example, in processes involving heating or combustion, the natural air circulation could be such that the maximum-risk employee might be working at a considerable distance from the source. Ventilation booths, air supply inlets, and open doors also affect airflow patterns. In addition to airflow, differences in work habits can significantly affect levels of exposure. Even though several employees work with the same materials, their methods and habits could affect the contaminant concentration to which they are exposed. If it is only testing at locations known to have been problematic in the past, Fingston may not be testing all of its most highly exposed employees.

4. A process flow sheet helps to show how and where each material is introduced into a process and at what points products and by-products are created. Process flow sheets and standard operation procedures (SOPs) should be updated as new elements are incorporated into a process because they provide a good description of the general operations involved and an excellent source of industry terminology. Since many hazards exist simultaneously, it is important to examine the overall process, identify air contaminants, and pinpoint the location and tasks of employees who might be exposed to them. Having updated process flow sheets that show where and how changes have been made to manufacturing process at Fingston would help the company implement a more efficient and effective hazard evaluation process.

# Chapter 16
# Air Sampling

## ANSWERS—Quiz 1

1. b
2. a
3. a
4. a
5. a
6. d
7. a
8. b

9. d

10. b

11. A breathing zone is defined as a hemisphere in front of the shoulders with a radius of 6 to 9 inches.

12. Air-sample collection devices are made of five basic components: an air inlet orifice, a collection device, an airflow meter, a flow-rate control valve, and a suction pump.

13. Breakthrough describes a condition in which the mass of a collected gas or vapor in the backup section is greater than 10 percent of the mass in the front section. This means that a significant quantity of the contaminant may not have been collected. The calculated concentration, therefore, is of questionable validity.

14. A wet-test meter is a partitioned drum, half-submerged in liquid, with openings in the center and periphery of each radial chamber. Air or gas enters at the center and flows into one compartment, causing the chamber to rise and rotate. The number of revolutions made by the chamber is recorded on a dial. Because the liquid is replaced by air, the measured volume depends on the height of the fluid, so a sight gauge is provided. Temperature and pressure gauges are also provided.

15. A rotameter consists of a float or ball that is free to move in a vertically tapered tube. Air is pulled through the tube so that the ball rises until there is an equilibrium between the force of gravity and the force of the air traveling upward. The flow rate is determined by reading the height of the float on an attached numerical scale. Rotameters are frequently used in the field to check pump flow rate periodically during full-shift sampling.

16. A critical orifice is a precisely drilled hole in a metal plate through which the airstream being sampled is directed. When certain parameters are met, the flow rate through the orifice remains constant despite conditions at the inlet (such as a clogged filter). A critical orifice attached to a sampling pump causes the pump to draw air at the desired flow rate. The principle of the method is to draw air through the orifice under critical flow conditions and constant upstream pressure.

## ANSWERS—Quiz 2

1. b

2. b

3. a

4. a

5. a

6. a

7. c

8. d

9. a

10 A field blank is used to determine whether an air sample has been contaminated during handling.

11. The advantages of grab sampling are that it is inexpensive, it is simple to use, and it normally collects 100 percent of the chemical. The disadvantage is that usually it cannot be used to sample reactive gases such as hydrogen sulfide, nitrogen dioxide, and sulfur dioxide unless the samples are analyzed immediately. Reactive gases can react with atmospheric dust particles, other gases, moisture, container sealant compounds, or the container itself, producing erroneous results.

12. Electrostatic precipitators are used when the required sample air volume is large, high-collection efficiency is required for very small particles such as fumes, there is a possibility of filter clogging, or high-temperature airstreams must be sampled.

13. The student must demonstrate a familiarity with this form by describing any part of its contents. The complete form can be found on pages 541-542 of the text.

14. A thermal desorption tube may contain several different sorbents in order to collect a wide range

of different chemicals. It is usually used in situations where unknown chemicals or a wide variety of organics are present, e.g., in indoor environmental air quality investigations.

15. Certain numbers of blanks are required by the analytical laboratory for each set of samples to be analyzed. Media blanks are simply unopened, new samplers that are sent with the samples. These unexposed, unopened samplers will give an estimate of media background.

16. The selection of a sampling method depends on the following factors:
    - the sampling objective (documenting exposures, determining compliance, pinpointing sources of exposure)
    - the physical and chemical characteristics of the chemical
    - the presence of other chemicals that may interfere with the collection or analysis of the chemical
    - the required accuracy and precision
    - regulatory requirements
    - portability and ease of operation
    - cost
    - reliability
    - type of sampling needed (area, personal, grab, integrated)
    - duration of sampling

## ANSWERS—Case Study

1. Personal air sampling is the preferred method of evaluating worker exposure to airborne chemicals. The worker wears a sampling device that collects an air sample. Area air samples can be used to evaluate background concentrations, locate sources of exposure, or evaluate the effectiveness of control measures. Grab samples are taken to measure the airborne concentration of a substance over a short period of time. Integrated air sampling is used to estimate a worker's 8-hour or 15-minute exposure to a particular substance.

2. Air sampling is used to evaluate employee exposure, assist in the design or evaluation of control measures, and document compliance with government regulations.

3. Air-sample collection devices are made of five basic components: an air inlet orifice, a collection device, an airflow meter, a flow-rate control valve, and a suction pump.

4. Dusts, fumes, smoke, and fibers are dispersed as solids; mists and fogs are dispersed as liquids. They range in size from visible to microscopic.

5. The filter is the most common collection device for particulates.

6. Other sampling techniques include impactors, impingers, elutriators, electrostatic precipitation, thermal precipitation, and cyclones.

7. The selection of a sampling method depends on the following factors:
    - the sampling objective (documenting exposures, determining compliance, pinpointing sources of exposure)
    - the physical and chemical characteristics of the chemical
    - the presence of other chemicals that may interfere with the collection or analysis of the chemical
    - the required accuracy and precision
    - regulatory requirements
    - portability and ease of operation
    - cost
    - reliability
    - type of sampling needed (area, personal, grab, integrated)
    - duration of sampling

# Chapter 17
# Direct-Reading Instruments for Gases, Vapors, and Particulates

## ANSWERS—Quiz 1

1. b
2. a
3. a
4. b

5. c

6. b, c

7. a

8. When certain proportions of combustible vapor are mixed with air and a source of ignition is present, a fire or explosion can occur. The range of concentrations over which this occurs is called the explosive (or flammable) range.

9. In the MOS gas sensor, a change in the electrical conductivity occurs when a combustible gas is adsorbed on the surface of a semiconductor. This change in electrical conductivity is proportional to the concentration of the combustible gas present.

10. Limitations that must be considered when using colorimetric detector tubes include the sensitivity of the tubes, their lower accuracy, the possible presence of interferences, and the potential lack of appropriate tubes for determining anything more than instantaneous concentrations.

11. The zero adjustment must be made by taking the instrument to a location that does not contain combustible gases or by passing air into it through an activated carbon filter that removes all combustible vapors and gases (except methane).

12. Portable or transportable electron capture detectors are used to evaluate fume hood performance through the release of sulfur hexafluoride at the face of the hood.

13. The open path infrared analyzer is intended for the detection of major leaks or spills of combustible or toxic gases within a distance of roughly 200 m.

14. In gas chromatography, the components of a volatile mixture migrate differentially through a separating column, transported by a carrier gas passing through the column. Optimally, differential migration takes place and each component separates as a discrete substance.

15. In comparison to other detectors that have been used for portable gas chromatographs, using a mass spectrometric detector is advantageous because the spectrometer has the ability to identify compounds in an unknown mixture by matching the fragmentation pattern of the unknown peak with that of knowns stored in a portable computer-based library.

16. The two principles that are the basis for combustible gas monitors are (1) the change in resistance of a conductor subjected to heat released by gas combustion, or (2) the change in electrical conductivity of a metallic oxide semiconductor in the presence of a combustible gas.

17. Many gases and vapors, both inorganic and organic, absorb certain characteristic frequencies of infrared radiation. This property and the resultant infrared spectrum can be used to identify and quantify compounds in the air that absorb in the infrared region.

## ANSWERS—Quiz 2

1. a

2. b

3. a

4. a

5. a, d

6. d

7. d

8. Air is drawn through the sampling probe and into the detector by means of a small sampling pump or a hand-operated squeeze bulb. In some cases, air diffuses into the instrument without being actively drawn in.

9. Because minute concentrations of silicone vapors—even 1 or 2 ppm—can rapidly poison the catalytic activity of the platinum filament, a hot-wire combustible gas indicator should not be used where silicone vapors are present.

10. Polarographic detectors rely on two parameters: (1) the ability of the compound of interest to be chemically oxidized or reduced at an electrode at a given electrode potential, and (2) the rate-determining step of the discharge of ions at a

microelectrode that is determined by diffusion.

11. A number of direct-reading instruments are not compound-specific or are specific for whole classes of compounds. These are of value as leak detectors or in atmospheres that are know to contain only a single contaminant.

12. Flame ionization detectors are highly sensitive to compounds that ionize in the presence of an oxyhydrogen flame. The ions are collected and the electric current generated for the compound of interest (whose response factor has been determined) can be translated into a concentration.

13. The ion mobility spectrometer was developed for rapid detection of toxic gases in combat situations.

14. The condensation nuclei counter is a type of highly sensitive particulate monitor that is used as a direct-reading instrument for the evaluation of fit factors in air-purifying respirators.

15. Great care must be exercised to ensure that a reading above the UEL is not misinterpreted as a true zero reading. A very high concentration of combustible gas can be identified by carefully watching the needle as the probe is moved into and withdrawn from the space being tested. At some point during entry and withdrawal, the instrument will exceed the LEL if a level above the LEL is actually present.

16. The basic principle for surface acoustic wave detectors is that acoustic waves are transmitted at a resonant frequency into a piezoelectric material. This material can be coated with a variety of different absorptive polymers. The resonant frequency is determined by the mass of the vapors present in the air that are absorbed by the polymer. Changes in that frequency can be measured and translated into a signal that is proportional to the concentration of a particular contaminant in the air.

## ANSWERS—Case Study

1. In many confined spaces, the oxygen content can become low enough to be life-threatening. In such situations, it is necessary to determine the oxygen content of the air. It is also necessary to take a sample to determine whether combustible gases are present in dangerous concentrations.

2. The oxygen level should be monitored in enclosed areas where combustion or other processes may use up the available oxygen. Excess oxygen from oxyacetylene or oxyhydrogen flame operations should also be monitored to prevent a fire hazard.

3. Multiple-gas monitors are available that can accommodate up to five different detectors at a time. These instruments are typically configured to include combustible gases and vapors, oxygen, and carbon monoxide, all of which are of interest in confined spaces.

# Chapter 18
# Methods of Control

## ANSWERS—Quiz 1

1. a
2. b
3. a
4. a
5. b
6. c
7. d
8. b
9. a
10. c
11. d

12. The three categories of methods are engineering controls, administrative controls, and personal protective equipment.

13. When more than one standard or agency is involved, the more stringent standard is assumed

to be controlling.

14. The five questions that should be asked are: to what degree is it possible to remove hazardous residues from a piece of equipment before it is opened, to what extent can a system be designed to be relatively maintenance-free, can a system be designed so that the entire operation can be conducted as a closed system, can the process be conducted automatically without worker involvement, and can the system be cleaned automatically without worker involvement.

15. When isolating toxic materials, the degree of isolation that is required depends on the toxicity of the contaminant, the amount released, and work patterns around the process.

16. The major disadvantage of general ventilation is that employee exposures can be very difficult to control near the source of the contaminant where sufficient dilution has not yet occurred.

17. An air-purified respirator removes a contaminant from the breathing air by filtering or chemical absorption; an air-supplied respirator provides clean air from an outside source or from a tank.

18. Hazard-oriented medical surveillance programs use biological indicators to monitor the absorption of chemical agents by analyzing the levels of the agent or its metabolite in the blood, urine, or expired air.

19. Substituting nontoxic or less toxic materials or equipment may be the least expensive and most positive way to control many occupational health hazards. Often substitution results in considerable savings for a company. As technology progresses, more information about the toxicity of materials becomes available and the list of possible substitutes grows. Sometimes it is possible to control or reduce a hazard simply by substituting one form of a material for another, such as substituting palletized or briquette forms of a material to reduce a dust hazard. When examining the possibility of substituting one material for another, industrial hygienists must be very careful to ensure that a previously unforeseen hazard, such as a synergistic interaction between chemicals, does not occur as a result of the substitution. In some cases, substitution may be impossible or impractical, such as with processes involving ionizing radiation.

20. Some of the factors that influence the proper design of exhaust ventilation systems include the temperature of the process, the physical state of the contaminant in question (dust, fume, smoke, mist, gas, or vapor), the way in which the contaminant is generated, the velocity and direction in which the contaminant is released to the atmosphere, and the contaminant's toxicity. Designing local exhaust systems can be difficult because hoods or pickup points must be correctly shaped and located to capture contaminants. The fan and ducts must draw the right amount of air through each hood. The characteristics of a contaminant and how it is dispersed determine which type of hood should be used. The hood should be located so that the contaminant is moved away from the operator's breathing zone. The type of contaminant, its concentration, and air pollution standards determine the selection of an air cleaner.

## ANSWERS—Quiz 2

1. b
2. a
3. a
4. a
5. b
6. c
7. a
8. d
9. b
10. a
11. b
12. The three basic steps that must be followed are: locate the contaminant source, establish the contaminant's path to the employee, and determine the employee's work pattern and use of protective equipment.

13. Even though administrative controls can limit the duration of individual exposures, they are difficult to implement and maintain.

14. In a closed system, raw materials are brought to a processing site in sealed containers and emptied into storage tanks or containers. This type of system keeps employee contact with materials to a minimum.

15. Locating one or more hazardous operations together in a separate building can reduce the number of workers exposed to the hazard and simplify the necessary control measures.

16. Employees should be prohibited from using compressed air to remove particulates from clothing because this practice causes the particulates to become airborne and increases the risk of employee exposure.

17. Cradle-to-grave responsibility reflects the fact that producers of hazardous waste are perpetually responsible for on-site and off-site damages to the environment, as well as worker and community health.

18. The difficulty involved in decontaminating the clothing and the endurance of the material used can determine whether disposable or reusable clothing should be chosen.

19. General ventilation can be used when small quantities of air contaminants are being released into the work environment at fairly uniform rates. It can also be used when there is sufficient distance between a worker and the contaminant source to allow sufficient air movement to dilute the contaminant to safe levels. If only contaminants of low toxicity are being used and if there is no need to collect or filter contaminants before the exhaust air is discharged into the community environment, then general ventilation may also be implemented. In addition, general ventilation may be used if there is no possibility of corrosion or other damage to equipment from the diluted contaminants in the work environment air. The exception to these criteria is using general ventilation for comfort control.

20. To help workers better understand the need for respirators, employers can require that workers use respirators only after every effort has been made to eliminate the hazard using engineering and administrative controls. Employers can also help workers feel more comfortable with the equipment by fully explaining the hazards to them and training them in the proper use and limitations of the equipment. The employer can also make sure the respirator fits the worker according to OSHA guidelines and that it is properly maintained and cleaned after every use.

## ANSWERS—Case Study

1. When Mayfield management begins designing its new facility, the use of personal protective equipment should be considered a last resort. Only if engineering or administrative controls are not possible or if they are not sufficient to achieve acceptable limits of exposure should personal protective equipment be required. The primary disadvantage of personal protective equipment is that it does not eliminate the hazard from the workplace. If the equipment fails, the worker is immediately exposed to the hazard. A protective device may become ineffective without the wearer's knowledge, resulting in serious harm. The integrity and fit of a personal protective device is vital to its effectiveness. In some cases, personal protective equipment may be appropriate during short exposures to hazardous contaminants, such as during nonroutine equipment maintenance or emergency responses to spills; however, if Mayfield management intends to require the use of the equipment over long periods of time, employees may not be as well protected from potential hazards as management believes.

2. If Mayfield management implements engineering and administrative controls and still requires the use of respiratory protection equipment in its new facility, there are several factors it must consider when selecting the equipment. It needs to identify the substance or substances for which respiratory protection is necessary and the tasks of the workers involved, as well as determine the hazards of each substance and its significant physical and chemical properties, particularly the presence or absence of oil particles. Management must also determine the maximum levels of air contamination expected, the probability of oxygen deficiency, and the condition of exposure. The period of time for which respiratory protection must be worn needs to be determined,

along with the capabilities, physical characteristics, and limitations essential to the safe use of the device. The facilities needed for maintenance must be identified, and the location of the hazardous workspace in relation to the nearest area with respirable-quality air must be determined. Management needs to consider occupational exposure limits for the substance or substances and respirator protection factors. In addition to these considerations, OSHA requires that employers establish a respirator program whenever the devices are used.

3. Wetting down dust is one of the simplest methods of dust control. Wetting down floors before sweeping to reduce the dispersion of dust is recommended when better methods, such as vacuum cleaning, cannot be used. The effectiveness of this method, however, depends on proper wetting. In some cases, a wetting agent, or surfactant, must be added to water. It is also important to dispose of the wetted dust properly before it dries out and is redispersed. Wet methods have been used in various industries to reduce dust hazards. For example, forcing water through drill bits has reduced dust concentrations in rock drilling operations. Many foundries clean castings using water under high pressure in place of sandblasting.

# Chapter 19
# Local Exhaust Ventilation

## ANSWERS—Quiz 1

1. a
2. b
3. a
4. a
5. b
6. b
7. a
8. b
9. b
10. d
11. b
12. Dilution systems reduce the concentration of contaminants released into the workroom by mixing with air flowing through the room. Either natural or mechanically induced air movement can be used to dilute contaminants. Local exhaust ventilation systems capture or contain contaminants at their source before they escape into the workroom environment. The main advantage of local exhaust systems is that they remove contaminants rather than just dilute them.
13. Hood selection is an area where the health and safety professional can make a significant contribution since the keys to good hood selection include the following: a knowledge of hood and airflow principles, an understanding of the plant processes, and a familiarity with employee work patterns around each process. In many plants, the health and safety staff has the best overall understanding of these three areas.
14. A major limitation to the use of receiving hoods is that gases, vapors, and the very small particles that can be inhaled and retained in the human respiratory system do not travel very far in the air unless carried by moving air. This means that receiving hoods are not very useful for health protection ventilation systems unless the process emits quantities of hot air or air with sufficient velocity to carry the respirable contaminants into the hood.
15. Stainless steel and specialty plastics are used where protection against corrosion is needed.
16. Major reasons for poor flow patterns are elbows, dampers, duct junctions, or other flow disturbances near the fan.
17. Major removal techniques for gases and vapors are absorption, adsorption, and oxidation.
18. A room or plant with insufficient makeup air is said to be "air bound" or "air starved."
19. Filter devices fall into two major categories: disposable and reusable. Filters may be made of

woven or felted (pressed) fabric, paper, or woven metal, depending on the application. They are available in a variety of configurations, such as mats, cartridges, bags, and envelopes. Filters have the general advantage of being able to handle varying exhaust gas flow rates and particle loadings.

20. FSP = (SP inlet) + (SP outlet) – VP inlet
FSP = fan static pressure, inches of water
SP = static pressure, inches of water
VP = velocity pressure, inches of water
Inlet/outlet = fan inlet and outlet

## ANSWERS—Quiz 2

1. a
2. a
3. b
4. b
5. a
6. b
7. c
8. b
9. c
10. d
11. Wind direction and velocity are important factors. If there is a prevailing wind direction at the site, it should help locate the stack on the downwind side of the roof. However, the location of the stack and air intakes should recognize that wind will often blow from other than the prevailing direction. A low wind speed allows the plume to rise due to the discharge velocity and any thermal head. As wind velocity increases, the first effect will be to decrease plume rise and the resulting dilution.
12. An insufficient quantity of makeup air may cause poor fan operation, inefficient combustion in furnaces, drafts, and problems with slamming doors in the work area.
13. The basic airflow concept in ventilation systems is called the "equation of continuity," which expresses mass balance as air flows through different parts of the system. The equation of continuity is expressed as $Q = V \times A$, where Q = airflow, $ft^3/min$; V = air velocity, ft/min; and A = area of airflow, $ft^2$.
14. Pressure can be measured directly in inches of water using a U-tube manometer. Mechanical pressure gauges and electronic transducer units calibrated in inches of water are also commonly used.
15. Air density is affected by the moisture content and temperature of air as well as the altitude above sea level.
16. Smoke tubes are glass tubes containing a chemical that produces a chemical fume (smoke) as room air is blown through the tube with a hand-operated bulb. They are useful for the following tests: evaluating the capture range of hoods; identifying drafts and other factors that can interfere with hood performance; demonstrating the capture distance of hoods to workers so they can position the hood or work item properly.
17. To measure static pressure in a duct, a small diameter hole is drilled through the duct wall. The holes should be at least 7.5 duct diameters downstream from any disturbance, such as an elbow. The end of a rubber tube attached to a U-tube manometer or other pressure sensor is pressed against the duct over the hole and the static pressure is read in inches of water.
18. Air flowing through the ductwork meets resistance in the form of friction and turbulence. Straight duct lengths result in friction loss, while elbows, junctions, air cleaners and other features cause turbulence losses.
19. A typical local exhaust system consists of the following elements. Hoods: any point where air is drawn into the ventilation system to capture or control contaminants. Ducts: the network of piping that connects the hoods and other system components. Fan: the air moving device that provides the energy to draw air and contaminants into the exhaust and through the ducts and other components. Air cleaner: a device to remove airborne materials that may be needed before the exhaust air is discharged into the community environment.

20. Static pressure tests in a system that once operated properly can help to identify the following fan problems: loose fan belt or another drive problem; material deposited on blades or blade erosion/corrosion; centrifugal fan motor wired incorrectly and therefore rotating backward. Typical locations to measure static pressure include Hoods, entries into main ducts, on each side of air cleaners, on each side of the fan, and at several points along long ducts.

## ANSWERS—Case Study

1. A typical local exhaust system consists of the following elements: hoods, ducts, fan, air cleaner.

2. The best type of hood for the task of spray painting the iron handrails is an enclosure hood. This surrounds the contaminant source as much as possible. Contaminants are kept inside the enclosure by air flowing in through openings in the enclosure. Student may mention a spray booth, which is a typical example of an enclosure hood.

3. Good room conditions are critical for proper enclosure performance, including sufficient replacement air, supply outlets located and designed to avoid drafts, and protection against disruptive air currents from open doors and foot traffic near the hoods.

4. The other types of hoods utilized in a local ventilation system include capturing hoods and receiving hoods. There are also slot hoods and canopy hoods.

5. The type of devices to consider depend primarily on the physical state of the contaminants, whether they are particulates or gases/vapors.

6. The student should choose a method for particulate removal and defend the answer.

7. Makeup air should be supplied through a planned system rather than through random infiltration. The system should have the following features: supply rate should exceed exhaust rate by about 10 percent; air should flow from cleaner areas to the plant; makeup air should be introduced into the occupied zone of the plant; air should be heated in winter to about 65 F, makeup air inlets outside the building must be located so that no contaminated air from nearby exhaust stacks or chimneys is drawn into the makeup air system.

# Chapter 20
# Dilution Ventilation of Industrial Workplaces

## ANSWERS—Quiz 1

1. b

2. a

3. b

4. d

5. Dilution occurs when contaminants released into the workroom mix with air flowing through the room. Either natural or mechanically induced air movement can be used to dilute contaminants.

6. The amount of dilution airflow required depends on the physical properties of the contaminant (molecular weight and specific gravity [compared to water]), rate of contaminant release, the target airborne concentration, and the overall safety factor.

7. The two main categories of fans are centrifugal fans and axial flow fans.

8. Smoke tubes are useful in identifying the air distribution patterns in the work area, the movement of contaminants from discrete sources, the direction of natural air movement, and problems such as short circuiting.

9. Tubeaxial fans are special propeller fans mounted inside a short duct section. The fan blades are specially shaped to enable the fan to move air against low resistance.

10. Convective heat emitted by hot sources is called "sensible" heat.

11. The major disadvantage of dilution ventilation is that the inherent uncertainties that exist in many of the design parameters require that large safety factors be applied to assure that exposures

are controlled. The uncertainties often result in large volumes of air being needed and may make dilution ventilation less cost-effective than local exhaust ventilation or another exposure control technique.

## ANSWERS—Quiz 2

1. b
2. a
3. c
4. a
5. Air movement due to temperature differences can be useful because hot processes heat the surrounding air, and the rising column of warm air will carry contaminants upward to roof vents.
6. The three different types of axial fans are propeller fans, tubeaxial fans, and vaneaxial fans.
7. Work in confined or enclosed spaces presents special hazards including oxygen deficiency, toxic contaminants, risk of engulfment by solid materials, and the risk of being trapped by small passageways.
8. Axial flow fans often used for dilution ventilation in enclosed spaces might exhibit a severe drop in airflow with added resistance to airflow. For each fan, the amount of air it can move depends on the resistance or static pressure it is operating against. In enclosed spaces, the extra resistance usually is due to either long lengths of duct attached to the fan or too small openings for make-up air, which causes a slight negative air pressure inside the space.
9. Dilution is often used to ventilate workspaces such as tanks and utility vaults that are usually unoccupied but are occasionally entered for inspection, cleaning, maintenance, or other tasks.
10. When both employee exposure and fire/explosion prevention are considered for the same operation, the dilution flow rate calculated using Equation 1 almost always governs because the allowable airborne levels for breathing are significantly lower than the lower explosive limit (LEL).

## ANSWERS—Case Study

1. Working in confined or enclosed spaces requires extraordinary care. A safety plan for work in these locations includes such features as preventing unauthorized entry, identifying and controlling the potential hazards, performing air monitoring, providing ventilation, providing rescue equipment and personnel, and training employees.
2. "Short circuiting" can occur if the air moves from the inlet to the exhaust fan without diluting contaminants where employees are working. It may be necessary to block off some air inlets or take other steps to assure good air distribution. In many applications, good air distribution is easier to achieve if fresh air is blown into the space using a flexible duct arrangement rather than using the fan to exhaust the space. The fresh air can be discharged into the area where people are working and will flow out available openings.

# Chapter 21
# General Ventilation of Nonindustrial Occupancies

## ANSWERS—Quiz 1

1. a
2. b
3. a
4. b
5. a
6. b
7. b
8. c
9. d

10. a

11. c

12. The measurement represented by cfm OA/person is the number of cubic feet of fresh outside air per minute per person.

13. It is important that supply air reach terminal velocity before reaching building occupants because at higher velocities it will cause drafts and, as a result, discomfort for occupants.

14. *Mixing factor* is the ratio of the amount of air required to dilute a contaminant to the ideal amount of air that should reduce it.

15. Supply air distribution in the occupied zone is determined by the number, location, and type of terminal devices, such as supply diffusers and return and exhaust grilles, that are used.

16. Simple measurements of supply air, outdoor air, return air, and occupied air space can indicate $CO_2$ levels in room.

17. The relationship that forms the basis for estimating airflow using tracer gas methods is: change in tracer-gas concentration = amount introduced – amount removed.

18. Microbiological growth can be minimized by keeping filter systems well maintained, by conducting regular HVAC maintenance, by using good housekeeping practices, by locating air intakes in noncontaminated locations, and by keeping all HVAC system components dry or drained.

19. Good mixing can be achieved by providing and correctly positioning an adequate number of supply and return registers. Registers should be placed so that air is circulated to where people are located in the zone. Freestanding fans can be set up for people located in areas of poor mixing. This final approach is often cost-effective and acceptable to building occupants. A common cause of poor mixing is furniture, which can change the movement of air. The partitions used in offices, windows, and walls can also negatively affect airflow.

20. If the space above the ceiling is being used for returning air, certain guidelines must be followed. First, any electrical wiring located there must be in conduit or coated with a special fire-resistant covering. Plastic piping and plastic air registers, such as polyvinyl chloride, should not be used because they produce smoke in the event of a fire. The space above the ceiling should be kept clean and dry to reduce bioaerosol amplification. Fire walls that extend to the floor above must be breached to allow the air to return to the air-handling unit. One way of doing this is to use backdraft dampers. Finally, ceiling tiles and access doors must be kept in place to ensure proper airflow in the occupied space.

## ANSWERS—Quiz 2

1. b

2. a

3. a

4. b

5. a

6. b

7. d

8. a

9. c

10. d

11. b

12. ASHRAE is the American Society of Heating, Refrigeration, and Air Conditioning Engineers, the primary North American association dealing with issues of indoor air quality. It has developed several standards related to indoor air quality.

13. A single constant value system is less energy efficient because first it cools the air at the central cooling coil, and then it reheats it at the final distribution point.

14. The formula for calculating mixing efficiency is $K_m = Q_{\text{actual}} / Q_{\text{ideal}}$

15. The three most important consensus standards are ASHRAE 62 on Ventilation for IAQ, ASHRAE 55 on Thermal Comfort, and ASHRAE 52 on Air Filtration.

16. The three phases are characterizing complaints and gathering background data, checking performance of ventilation systems and their controls, and measuring carbon dioxide, temperature, and relative humidity.

17. The three tracer gas methods are the concentration-decay method, the constant-emission method, and the constant-concentration method.

18. If the air in a work space smells musty, there might be microbiological contamination in the ductwork.

19. To maintain temperature, a variable air volume system varies the amount of air delivered to a space. As the temperature of a space decreases to the desired level, the airflow diminishes. Since air volume and fan speed are linearly related, if airflow is cut in half, then fan speed is cut in half, saving energy and money. Another factor in the relationship between air volume and fan speed is horsepower and speed, which have a third-power relationship. If speed is reduced by half, horsepower and the costs associated with it are reduced by eight. Using fan inlet dampers to reduce airflow also lowers costs, but not by the same factor as reducing fan speed. By installing variable-volume boxes at the distribution point, more zones can be supplied by a single fan. As the demand for air decreases, dampers at the boxes close, the fan slows, and energy is saved. If a building uses dual ducts for cool and warm air to maintain a minimum OA supply, mixing boxes can mix the air at the minimum flow required for temperature control and OA delivery, allowing the fan to run at a lower rpm, saving energy, and lowering costs.

20. Commissioning is used to identify, verify, and document the performance of a new HVAC system to ensure proper operation and compliance with codes, standards, and design intentions. A commissioning agent is often chosen by the building owner, the architect, or the contractor to oversee construction and commissioning activities. These activities often involve tests and demonstrations to verify that a system is operating properly. Troubleshooting and maintenance activities also require testing the system.

## ANSWERS—Case Study

1. The standard for thermal quality is ASHRAE 55-1992: *Thermal Environmental Conditions for Human Occupancy.* For a company to comply with the standard, 80–90 percent or more of occupants in an environment should find the environment thermally acceptable. The standard attempts to predict what conditions of temperature, humidity, activity, clothing, air movement, and radiant heat sources will satisfy 80–90 percent of people. At least 90 percent of people should be satisfied with any single parameter, and satisfaction for all parameters collectively should be 80 percent or more. ASHRAE 55-1992 does not cover other environmental factors such as air quality and contaminants.

2. Temperatures that are too warm or too cold are a common problem. Some of the reasons for this problem may be a misadjusted thermostat, too much or too little supply air, a malfunctioning or misplaced temperature sensor, or a defective or undersized HVAC system. In other cases, the supply air temperature setting may be too high or too low, the supply diffuser may be blowing directly on employees, cold air may not mixing with the occupied air space, or the building may be under negative pressure. If a building is under negative pressure, air could infiltrate at the building perimeter. Building pressures should be +0.03 to +0.05 in. wg. A thermometer, a velometer, and smoke tubes can be used to test the HVAC system for these problems.

   A lack of air movement is a common problem with older variable air volume systems. The problem may arise when the system is set to deliver no air when cooling is not being requested. If an environment is stuffy or the air is stagnant, the problem may be that the filters are overloaded, the dampers on the variable air volume system may be malfunctioning, some of the ductwork may have disconnected from supply diffusers, or the ducts may be leaking. Nondelivery or low delivery of air to the space, restrictions in ductwork, inadequate delivery of outside air, and blockage from furniture, partitions, or other barriers may also lead to this problem.

3. To test stuffy or stagnant air, a thermometer, a velometer, smoke tubes, and a $CO_2$ meter can be used.

# Chapter 22
# Respiratory Protection

## ANSWERS—Quiz 1

1. b
2. b
3. a
4. b
5. a
6. c
7. a
8. d
9. b
10. d
11. d
12. A respiratory must be National Institute for Occupational Safety and Health (NIOSH) approved.
13. Respirators can impose several physiological stresses ranging from very mild restriction of breathing to burdens of great weight and effort. The type of effects produced depends on the type of respirator in use, the job, and the workplace conditions. For this reason, a physician or other licensed health care professional must determine whether or not an employee has any medical conditions that would preclude the use of respirators.
14. A user seal check is a test conducted by the wearer to determine if the respirator is properly adjusted to the face. The procedures may vary slightly from one user to another due to differences in construction and design. In general, the employee is checking either for pressure or flow of air around the sealing surface.
15. Once a NIOSH-approved respirator has been selected, the user should become acquainted with the limitations of the device as set forth in the approval. The approval will be void if the device is used in conditions beyond the limitations set by NIOSH or those established by the manufacturer. The user should also guard against any alteration being made to the device. All parts, filters, canisters, cartridges or anything else not specifically intended to be used on the device by NIOSH or the manufacturer will void the existing approval.
16. The most common starting carbon materials for respirator cartridges are coconut and coal.
17. Service life of a respirator depends on quality and amount of sorbent; packing uniformity and density; exposure conditions, including breathing rate of the wearer relative humidity, temperature, contaminant concentration, the affinity of the gas or vapor for the sorbent, and the presence of other gases and vapors.
18. There is a typical wide variation of odor threshold in the general population. Other problems exist: shift in odor threshold due to extended low exposures, shifts due to simple colds and other illnesses, and failure to recognize odors because of distraction of the workplace competing for worker attention. Given the variability among people with respect to detection of odors and differences in measuring odor thresholds, a better practice is to establish cartridge change-out schedules.
19. A written respiratory protection program must be established when respiratory protection is needed. It should include worksite-specific procedures covering the following minimum program elements:
    - procedures for selection of proper respiratory-protective equipment including exposure assessment
    - procedures for medical evaluation of respirator wearers
    - procedures for fit testing of workers using tight-fitting respirators
    - procedures for proper respirator use during routine and reasonably foreseeable emergency situations
    - procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, and

discarding respirators
- procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators
- procedures for training workers on respirator use and respiratory hazards
- procedures for regular program evaluation

20. Each respirator wearer must be able to demonstrate knowledge of at least the following:
    - why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator
    - what the limitations and capabilities of the respirator are
    - how to use the respirator effectively in emergency situations, including situations in which the respirator malfunctions
    - how to inspect, put on and remove, use, and check the seals of the respirator
    - what the procedures are for maintenance and storage of the respirator
    - how to recognize medical signs and symptoms that may limit or prevent the effective use of respirators
    - the general requirements of the OSHA respiratory protection standard

## ANSWERS—Quiz 2

1. a
2. a
3. a
4. a
5. b
6. b
7. c
8. a
9. a
10. c
11. d
12. As defined in the text, oil is any of numerous mineral, vegetable, and synthetic substances and animal and vegetable fats that are generally slippery, combustible, viscous, liquid, or liquefiable at room temperatures, and soluble in various organic solvents such as ether but not in water.
13. A combination type, full-facepiece pressure-demand airline respirator with auxiliary self-contained air supply OR a full-facepiece pressure-demand or other positive pressure self-contained breathing apparatus certified for a minimum service life of 30 minutes.
14. Respiratory-protective devices are being used to reduce exposure to aerosolized drugs and bioaerosols. This area presents many challenges including unknown safe levels of exposure for these agents or respirator efficacy for bioaerosols. Acceptable airborne levels have not been established for many pharmaceutical drugs or potentially infectious aerosols. NIOSH approved or certified respirators have not been tested against bioaerosols such as TB.
15. The qualitative fit-test protocols consist of three steps: threshold screening, respirator selection, and fit testing.
16. The procedure for cleaning respirators includes the following steps: Remove filters, cartridges, or canisters. Disassemble facepieces. Discard or repair any defective parts. Wash components in warm water with a mild detergent or with a cleaner recommended by the manufacturer. A stiff bristle brush may be used to facilitate dirt removal. Rinse components in clean, warm water and drain. When the cleaner used does not contain a disinfecting agent, respirator components should be immersed for two minutes in an appropriate solution as outlined in 29 *CFR* 1910.134. Rinse components thoroughly in clean, warm water and drain. Dry by hand with a lint-free cloth. Reassemble and test to make sure it is working properly.
17. Close off the exhalation valve and exhale gently into the facepiece. The face fit is considered satisfactory if a slight positive pressure can be built up inside the facepiece without any evidence of outward leakage of air at the seal.
18. CNP test exercises include: Normal breathing for one minute followed by 10 seconds of held

breath; deep breathing for one minute followed by 10 seconds of held breath; turning head side to side for one minute followed by 10 seconds of held breath; moving head up and down, etc.; reading aloud a prepared passage or counting backward from 100; grimace for 15 seconds; bend at the waist and touch toes for 1 minute.

19. Atmosphere-supplying respirators fall into three groups: air-line respirators, self-contained breathing apparatus, and combination air-line and SCBA. Air-line respirators deliver breathing air through a supply hose connected to the wearer's facepiece or head enclosure. The breathing air is supplied through the hose from either a compressor or compressed air cylinders. The SCBA provides respiratory protection against gases, vapors, particles in an oxygen deficient atmosphere. The wearer is independent of the surrounding atmosphere because the breathing gas is carried by the wearer. The combination units are air-line respirators with an auxiliary self-contained air-supply combined into a single device.

20. The steps for hazard determination are as follows:
    a. If the potential for an oxygen-deficient atmosphere exists, measure the oxygen content.
    b. Determine what contaminants may be present in the workplace.
    c. Determine whether there are Threshold Limit Values® (TLVs), Permissible Exposure Limits (PELs) or any other available exposure limits.
    d. Determine if the IDLH concentration for the contaminants is available.
    e. Determine if there is a substance-specific health standard for the contaminants. If so, there may be specific respirators required that will influence the selection process.
    f. Determine the physical state of the contaminant. If the contaminant is an aerosol, determine whether the vapor pressure is significant at the maximum expected temperature of the work environment. In these situations it may be possible to have a significant portion of the contaminant concentration in the vapor phase, requiring respiratory protection for both the particle and vapor phase of the contaminant.
    g. Measure or estimate the concentration of the contaminant.
    h. Determine whether the contaminant can be absorbed through the skin, cause skin sensitization, or be irritating to or corrosive to the eyes or skin. Respirators that provide skin or eye protection or air-supplied suits may be required in addition to providing protection from the inhalation hazard.
    i. For gases or vapors, determine if a known odor, taste or irritation threshold exists because these may provide a secondary indication for cartridge breakthrough.

## ANSWERS—Case Study

1. A written respiratory protection program must be established when respiratory protection is needed. It should include worksite-specific procedures covering the following minimum program elements:
    - procedures for selection of proper respiratory-protective equipment including exposure assessment
    - procedures for medical evaluation of respirator wearers
    - procedures for fit testing of workers using tight-fitting respirators
    - procedures for proper respirator use during routine and reasonably foreseeable emergency situations
    - procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, and discarding respirators
    - procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators
    - procedures for training workers on respirator use and respiratory hazards
    - procedures for regular program evaluation

2. Each respirator user must be able to demonstrate knowledge of the following:
    - why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator
    - what the limitations and capabilities of the respirator are
    - how to use the respirator effectively in emergency situations, including situations in which the respirator malfunctions
    - how to inspect, put on and remove, use, and check the seals of the respirator
    - what the procedures are for maintenance and storage of the respirator
    - how to recognize medical signs and symptoms that may limit or prevent the effective use of respirators

- the general requirements of the OSHA respiratory protection standard

3. Employees should have follow-up training at least once a year.

4. The respirators must be properly stored in order to protect them from dust, sunlight, excessive heat, extreme cold, excessive moisture, damaging chemicals, and physical damage from things such a vibration and shock. Tool boxes, paint spray booths, and lockers are not appropriate storage locations unless they are protected from contamination, distortion, and damage. In addition, emergency and rescue use respirators that are located in the work area must be readily accessible. Their location must be clearly marked.

5. The program administrator's responsibilities include the following:
   - conducting exposure assessments of the work area prior to respirator selection and periodically during respirator use to ensure that the proper respirator is being used
   - selecting the appropriate respirator that will provide adequate protection from all contaminants present or anticipated
   - maintaining records as well as the written procedures in a manner that documents the respirator program and allows for the evaluation of the program's effectiveness
   - evaluating the program's effectiveness through ongoing surveillance of the program

# Chapter 23
# The Industrial Hygienist

## ANSWERS—Quiz 1

1. a

2. b

3. b

4. b

5. d

6. Industrial hygienists must be competent in a variety of scientific fields—principally chemistry, engineering, physics, toxicology, and biology.

7. Some examples of health and safety activities that may be performed by Occupational Health and Safety Technologists are (1) safety inspections; (2) industrial hygiene monitoring; (3) organizing and conducting health and safety training; and (4) investigating and maintaining records of occupational accidents, incidents, injuries, and illnesses.

8. In an industry setting, the industrial hygiene manager supervises the technical and support staff in a health and safety department; prepares budgets and plans; is familiar with government agencies related to the operation; relates industrial hygiene operations to research and development, production, environmental, and other department or functions; and prepares appropriate reports.

9. CIHs can earn certification maintenance points by working as an industrial hygienist; participating in professional associations; attending approved meetings, seminars, and short courses; participating on technical committees; publishing in peer-reviewed journals; teaching, when not part of their primary practice; and other approved activities.

10. In 2001, the American Board of Industrial introduced Certified Associate Industrial Hygienist (CAIH) program.

11. The Education and Research Centers provide continuing education to occupational health and safety professionals; combine medical, industrial hygiene, safety, and nursing training so that graduates are better able to work effectively in complex and diverse conditions; conduct research; and conduct regional consultation services.

12. The Accrediting Board of Engineering and Technology has accredited master's level programs in industrial hygiene since 1985 and currently also accredits baccalaureate level programs.

13. The American Industrial Hygiene Association defines industrial hygiene as the anticipation,

recognition, evaluation, and control of environmental factors arising in or from the workplace that may result in injury, illness, or impairment, or affect the well-being of workers and members of the community.

14. Candidates for the OHST certification need five years' experience in occupational health or safety activities that comprise at least 35 percent of job duties, must pass the OHST examination, and complete certification maintenance requirements every five years. Candidates may substitute college courses in health and safety or an associate degree or higher in certain disciplines for up to two years of the experience requirement.

## ANSWERS—Quiz 2

1. a

2. a

3. a, c

4. c

5. a

6. In the civil service sector, the senior industrial hygienist differs from the industrial hygienist in receiving more complex assignments and acting in place of the industrial hygiene supervisor when the supervisor is absent.

7. The training program for OSHA compliance safety and health officers, instituted in 1992, is designed to provide a series of training courses supported by on-the-job training and self-instructional activities to ensure that compliance personnel are able to apply technical information and skills to their work.

8. Before attending the initial compliance course at the OSHA Training Institute, each OSHA CSHO must complete three self-study program: (1) the OSHAct, (2) Chapter III of the *Field Inspection Reference Manual*, and (3) Integrated Management Information Systems forms 1, 1A, 1B, and 1B-1H.

9. Once the training period is completed, CSHOs are required, at a minimum, to attend a technical course once every three years at the OSHA Training Institute.

10. The American Conference of Governmental Industrial Hygienists sets Threshold Limit Values® and updates these values annually.

11. The mission of the OSHA Office of Training and Education is to provide a program to educate and train employers and employees in the recognition, avoidance, and prevention of unsafe and unhealthful working conditions and to improve the skill and knowledge levels of personnel engaged in work relating the Occupational Safety and Health Act of 1970.

12. Specific responsibilities of the OSHA Training Institute include: (1) conducting programs of instruction for federal and state compliance officers, state consultants, other federal agency personnel, and private sector employers, employees, and their representatives; and (2) participating in the development of course outlines, detailed lesson plans, and other educational aids necessary to carry out training programs.

## ANSWERS—Case Study

1. For industrial hygiene trainees, assignments are selected and designed to orient the new employee into the field of industrial hygiene, to determine areas of interest and potential, to relieve experienced industrial hygienists of detailed and simple work, and to develop the trainee's knowledge and competence. Specific assignments are carried out under direct supervision of a qualified industrial hygienist, including recognition and evaluation of hazards, identification of controls, calibration of equipment, collection of samples, and initial preparation of reports.

2. Because compliance safety and health officers must be familiar with general concepts of safety and health, each CSHO is required to complete crossover training during the developmental period—that is, CSHOs on the safety or construction track are encouraged to attend the introduction to health course, while industrial hygienists are encouraged to attend the introduction to safety course.

# Chapter 24
# The Safety Professional

## ANSWERS—Quiz 1

1. a
2. b
3. a
4. b
5. a
6. d
7. a
8. c
9. b
10. a
11. c
12. The ASP designation is awarded to safety professionals who have passed the Safety Fundamentals Examination.
13. In addition to the government, the manufacturing, service, construction, insurance, and consulting sectors are the largest employers of safety professionals.
14. The decision about who should assume full staff responsibility for safety activities is influenced by the size of the organization and the nature of the hazards involved in its operation.
15. The "four Ms" and the "three Es" of safety are examples of accident investigation techniques.
16. Job safety analysis is an important part of employee training because it details all the necessary safety elements related to a task and, therefore, can be used by supervisors to train employees in safe work practices.
17. The five steps are hazard identification, hazard elimination, hazard protection, maximum possible loss, and loss retention.
18. Supervisors are key players in any safety and health program because they are responsible for translating management's policies into action and for promoting safe and healthful work practices among employees. Supervisors' attitudes toward safety and health will be reflected by the employees in their departments.
19. One trend that has emerged in the development of safety professionals is related to the increasing emphasis on analyzing the loss potential of the activity with which the safety professional is concerned. This type of analysis requires greater ability to predict where and how events resulting in injury and loss will occur and to find ways of preventing such events. Another trend involves the increased development of factual, unbiased, and objective information about loss-producing problems and reasons for accidents. This information enables those who have ultimate decision-making responsibilities to make sound decisions. A third trend is connected to the increasing use of the safety professional's help in developing safe products. Applying the principle of accident causation and control to product design or production has become more important because of product liability cases; legal issues in the field of safety and health, including negligent design; and the impact safer products have on the overall safety and health of the environment.
20. There are many advantages to having a third party conduct a safety inspection. For example, an independent inspection team is less likely to be biased in its findings and reports. The results of third-party inspections generally are directed to a higher level of decision-making body and, therefore, are more likely to be acted on promptly. Safety inspections can be more convenient if they are conducted by a third party since they are not dependent on the schedule of organization staff. In addition, the safety professionals contracted for third-party inspections usually have extensive experience in a given industry.

## ANSWERS—Quiz 2

1. a

2. a
3. b
4. b
5. a
6. c
7. a
8. d
9. b
10. a
11. a
12. The BCSP is responsible for establishing the criteria for professional certification, accepting applications, evaluating the credentials of candidates, and issuing certificates to those who met the requirements.
13. A loss control representative helps companies that are insured or seeking to be insured identify risks within their operations and reduce the possibility of accidents, fires, and other losses.
14. The purpose statement is often followed by general requirements and a procedure, including the designation of individuals or positions along with their special tasks or action steps.
15. The number of safety professionals and inspectors needed for adequate safety inspection activities primarily depends on the size of a facility, the complexity of a facility, and the type of industry involved.
16. The benefits of conducting a job safety analysis include training individuals in safe, efficient procedures, instructing new employees on safety and health procedures, preparing for planned safety and health observations, providing "prejob" instructions on irregular jobs, and reviewing procedures after accidents occur.
17. Spot-checking, reporting by repair control centers, and auditing are the three basic elements of a damage control program.
18. An individual can qualify for the title of Certified Safety Professional by applying to the Board of Certified Safety Professionals (BCSP), meeting an academic requirement, meeting a professional safety experience requirement, passing the Safety Fundamentals Examination, and passing the Comprehensive Practice Examination.
19. One reason for the increased number of full-time safety professionals is the Occupational Safety and Health Act (OSHA), which was passed in 1970. The act requires that certain safety standards be met and maintained. A second reason is related to a better understanding of the safety professional's services and functions. The safety professional responsible for administering a safety program must be highly trained and/or have many years of experience in the safety field.
20. Management can use safety inspections to show employees that it is concerned about their safety and health. Every time a safety professional or inspection team evaluates a work area, management demonstrates its interest in employees' safety and health. If unsafe conditions are identified during an inspection, management can show employees its concern for their well-being and its interest in accident prevention by correcting the situation immediately. Inspections can also help to bolster employee interest in management's safety and health program and encourage employees to inspect their workstations regularly. Regular inspections enable safety professionals to become familiar with employees and more readily gather information from them. By acting on employee suggestions, management also demonstrates that to employees that their cooperation is vital and appreciated.

## ANSWERS—Case Study

1. A good record-keeping system gives safety professionals the means for doing an objective evaluation of the magnitude of occupational illness and accident problems. It also provides them with a measurement of the overall progress and effectiveness of the safety and health program. It helps identify high-hazard units, facilities, or departments, and

problem areas so that extra efforts can be focused on those areas, and provides the data needed to analyze accidents and illnesses and pinpoint specific circumstances of occurrence, which can then be addressed using specific countermeasures. A good system promotes interest in safety and health among supervisors by furnishing them with information about the accident and illness history of their own departments. In addition, it provides supervisors and safety committees with hard facts about safety and health problems so that they can focus their efforts, and helps measure the effectiveness of individual countermeasures and determine whether specific programs are doing the job that they were designed to do. An effective record-keeping system can help establish the need for, and the content of, employee and management training programs that can be tailored to fit the particular needs of an organization or facility.

2. Safety professionals at Jackson Metals can help the purchasing department by providing it with specific information about safety and health hazards that can eliminated by changes in design or by having the manufacturer install guarding. They can also provide information about equipment, tools, and materials that can cause injuries if misused and offer specific information about health and fire hazards at the facility's worksites. Safety professionals can serve as resources for information on federal and state safety and health rules and regulations, and on the accident history of machines, equipment, or materials that are about to be reordered.

3. When the cost-effectiveness method is used, the cost of system changes made to increase safety and health measures is compared with either the decreased costs of fewer serious failures or with the increased effectiveness of a system to perform its task, in order to determine the relative value of these changes. Ultimately, all system changes have to be evaluated, and this method makes such comparisons explicit. Cost-effectiveness analysis is often used to help make decisions concerning the choice of one of several systems that can perform the same task.

# Chapter 25
# The Occupational Medicine Physician

## ANSWERS—Quiz 1

1. a
2. b
3. b
4. b
5. a
6. a
7. c

8. The student may list three of the following: use of anesthesia, aseptic technique, development of diagnostic instruments such as the stethoscope and ophthalmoscope, tests such as x rays and electrocardiograms, identification of organisms causing diseases such as cholera and tuberculosis and development of vaccines for use against them, combined with standardized population-based tests for vision, height/weight, and IQ.

9. Occupational medicine is now a sub-specialty of the medicine division or its own department in many large medical group practices, hospitals, and universities. Freestanding occupational health clinics, often combined with urgent-care centers, offer another practice setting. Private consulting firms and international work are two growing sectors. Academic, occupational, and environmental health departments are another major development.

10. All physicians graduating medical school after 1984 are required to take a formal occupational medicine residency or fellowship program in order to become eligible to take the Occupational Medicine Board Examination. The program is two years, usually after a full or partial residency in another field such as internal medicine.

11. The student will name one of the following: American College of Occupational and Environmental Medicine, American Public Health Association, or The National Association of Occupational Health Professionals.

12. The student may write an essay touching on some of these key factors: Clinics may be a single entity or part of a chain of clinics located near industry and may provide a wide range of services from preplacement examinations and drug testing to acute care for work-related injuries and illnesses. These clinics do not usually have the same access to specialized services as hospital or multi-specialty group practice programs. Often practitioners in these clinics are required to see 30 or more patients per day. Doctors in these clinics may not be specialists in the field, and may not focus on injury illness treatment or preplacement and surveillance examinations. Mostly, physicians working in these clinics will have little time or training to deal with complex health and safety issues.

## ANSWERS—Quiz 2

1. a
2. b
3. a
4. a
5. d
6. c
7. a
8. A resident's program will include significant public health training in toxicology, epidemiology, statistics and a practicum year of clinical, research, and corporate placements, and public sector agency rotations.
9. This career choice allows a wide range of practice opportunities, including consulting with companies, local government agencies, and unions, performing medical surveillance and other examinations, acting as expert witnesses, and doing epidemiological research. Frequently, these specialists have close working relationships with industrial hygienists, epidemiologists, toxicologists, and occupational health nurses, or have them on staff.
10. The student may answer with any of the questions or statements from the Occupational History Form found on pages 770-771 of the text. Sample statement: List hobbies and active sports you do such as painting, woodworking, welding, hairdressing, scuba diving, etc.
11. Preplacement examinations are an important part of ensuring a safe and healthy workforce as hiring those physically unable to do the job tasks places an added burden and risk of injury of coworkers. Preplacement evaluations can range from a simple drug screen, a medical history review by a registered nurse to a complete medical and occupational history and physical examination with functional capacity testing and other tests.
12. The corporate medical department is an area of occupational medical practice that is shrinking due to organizations downsizing and contracting out. Today's corporate medical director will likely be a consultant to human resources, helping provide quality assurance over the contract clinics which actually provide the services, and aiding in reviewing and negotiation with health plans, medical review for difficult workers' compensation cases, ADA and fitness for duty issues, development of protocols for exposures, and medical surveillance.

## ANSWERS—Case Study

1. For this question, the student should demonstrate a thorough understanding of the job opportunities for an occupational medicine physician by listing four of the following eight practice settings: corporate medical department, multispecialty group practice/hospital based programs, freestanding occupational health clinic, private consulting firms, academic occupational medicine departments, government agencies, international occupational health consulting, union occupational health physician. The student will back up their list with specific job tasks for each

practice setting.

2. All physicians graduating medical school after 1984 are required to take a formal occupational medicine residency or fellowship program in order to become eligible to take the Occupational Medicine Board Examination. The program encompasses two years, usually after a full or partial residency in another field, such as internal medicine.

3. The program content includes significant public health training in toxicology, epidemiology, and statistics, and a practicum year of clinical research and corporate placements, and public sector agency rotations.

4. The test is offered once a year by the American Board of Preventive Medicine. Approximately 200-300 physicians take the test annually.

5. Students must relate their answer to the form found in their textbook. This form questions an employee regarding the exposure to potential physical, chemical, biological and psychological hazards; the type of personal protective equipment worn on the job; secondary work experiences; hobbies and activities he or she may participate in; problems with fertility; and if he or she has ever had any work-related experience believed to have been harmful.

# Chapter 26
# The Occupational Health Nurse

## ANSWERS—Quiz 1

1. b
2. a
3. a
4. b
5. c

6. Occupational health nurses provide care to employees with the goal to prevent work-related injury and illness, prevent disability, and help workers achieve and maintain the highest level of health throughout their lives.

7. The Certified Occupational Health Nurse (COHN) and the Certified Occupational Health Nurse Specialist (COHN-S) credentials are awarded by the American Board of Occupational Health Nurses.

8. Certification is awarded based on specific educational preparation, current occupational health work experience, evidence of continuing occupational health and safety education, and successful completion of an examination.

9. Additional academic preparation as a manager, nurse practitioner, or clinical nurse specialist in occupational health nursing is available at the graduate level at university-based, NIOSH-funded educational research centers.

10. In addition to the OHN, other members of the occupational health services team might include an industrial hygienist, occupational medicine physician, safety professional, ergonomist, physical therapist, employee assistance program personnel, and rehabilitation counselor.

11. Secondary prevention is the early detection and treatment of disease and injury so that progression is slowed or complications are limited.

12. The OHN is licensed as a registered nurse and has both independent and dependent nursing functions, as authorized by the state business and professions code. Advanced practice nursing roles are also licensed, state by state, and include those registered nurses prepared at the graduate degree level in the roles of clinical specialist, nurse practitioner, nurse midwife, and nurse anesthetist.

13. The scope of occupational health services depends on the following key industry variables: (1) company size and demographics of the work force; (2) geographic distance of a health care facility in the community; (3) type of industry; (4) hazard profile; (5) risk management and

health benefit philosophy of company, percent of insured work force; (6) economic resources; (7) self-insurance status for workers' compensation and personal health care; and (8) organizational climate.

## ANSWERS—Quiz 2

1. b
2. a
3. b
4. b
5. c
6. a, d
7. Approximately 45,000 adults in the United States die annually of complications from influenza, pneumococcal infections, and hepatitis B, the primary vaccine-preventable diseases affecting adults.
8. Examples of OHN employee training activities include: (1) education on how to adjust workstations and work flow to prevent cumulative trauma disorders; (2) education on the long-term effects of noise and the need for hearing protection; and (3) education and demonstration on proper lifting techniques and back-strengthening techniques.
9. Approximately 33 percent of all private, nonagricultural worksites with more than 50 employees reported having an EAP resource for their employees.
10. Practice guidelines are clinical practice recommendations based on a critical review of research/evidence. Some are focused on the diagnosis of a specific health condition, and other focused on the clinical management of a health condition, with the key aim to standardize care.
11. Occupational health surveillance is the process of monitoring the health status of worker populations to gather data about the effects of workplace exposures and to use the data to prevent illness or injury. The goal is early identification of biological markers or endpoints that may signify exposure.
12. Case management is the timely coordination of quality health services with the goal to decrease fragmentation of care, enhance the client's quality of life, and contain health care costs.
13. New health and safety regulations, mental health issues in the workplace, the continued increase in cumulative trauma disorders, chronic illness and the aging work force, the increased numbers of women in the work force, and the changing health care delivery structures are only a few of the current health issues facing employers and occupational health services.
14. A 1988 survey of Fortune 500 companies noted the four most frequent occupational health nursing activities were (1) supervising the provision of nursing care for job-related emergency and minor illness episodes; (2) counseling employees about health risks; (3) providing case management for employees with workers' compensation claims; and (4) performing periodic health assessments.

## ANSWERS—Case Study

1. Establishment of an ergonomics program requires knowledge, skills, and abilities in the following areas:
   - the diagnosis and treatment options for repetitive strain injuries (clinical and primary care)
   - program design with policy and procedures (management)
   - the ability to educate workers regarding neutral wrist position and postural issues (education/training; health promotion and disease prevention)
   - knowledge of ergonomics legislation and the Americans with Disabilities Act (regulatory/legislative)
   - a team approach to analyze the workstations and institute engineering controls (work force, workplace, environmental/research, and professionalism).
2. An ergonomics program consists of management commitment, worksite analysis, hazard prevention and control, medical management, and training and education.

# Chapter 27
# The Industrial Hygiene Program

## ANSWERS—Quiz 1

1. a
2. a
3. b
4. b
5. a
6. d
7. d
8. c
9. a
10. The four stages of the Demming cycle are plan, do, check, and act.
11. The requirements and procedures outlined in a written industrial hygiene program identify what should be done, how it should be done, who should do it, and how often.
12. Employees are organized into SEGs so that monitoring data can be applied to individuals who were not directly monitored, but who might be represented by the samples collected.
13. It is important to determine whether training can solve a problem because training can address lack of knowledge or incorrect knowledge, but it cannot effectively address lack of motivation or attention to the job.
14. The documentation must be maintained to show that the program has been conducted in accordance with professional standards. The data collected may also be useful for future industrial hygiene or medical evaluations.
15. A health professional needs to have a good understanding of what is manufactured, how it is manufactured, the potential safety and health hazards associated with these manufacturing processes, and the physical requirements of the various jobs to run an effective medical program.
16. An organization's purchasing department contributes to workplace safety by ensuring that only equipment and material approved by the organization's industrial hygiene, safety, environmental, or other responsible reviewing teams are purchased. The department also promotes workplace safety by obtaining material data sheets for all chemicals purchased.
17. An audit generally begins with an opening conference between the auditors and the management of the facility. During the conference, the purpose, scope, and schedule of the audit are discussed. The second step in the audit process involves gathering the information. Then the information is analyzed, key facts are confirmed, and any contradictions are resolved. After analyzing the data, the auditors can usually generalize from specific situations to underlying program deficiencies. They then present their conclusions to the facility's management and discuss any remaining concerns. As the last step in the process, a report is issued detailing the auditors' findings.
18. A safety and health committee is a forum for securing cooperation and coordination from among those groups involved in a safety and health program. It also is a forum for exchanging ideas on safety and health issues. The committee provides a means of involving employees in the program safety and health program. It is responsible for examining company safety and health issues and recommending changes in practices or policies to management. It also conducts periodic inspections of the workplace in addition to evaluating and promoting interest in a company's safety and health program.

## ANSWERS—Quiz 2

1. a
2. b
3. a

4. a

5. b

6. c

7. b

8. d

9. a

10. A goal is a desired outcome; an objective is a specific activity or means of achieving a goal.

11. Workers that should be included in SEGs are those who can be expected to have the same or similar exposure profiles to an environmental agent based on the information gathered during workplace, work force, and agent characterizations.

12. It is important to have a written procedure for sampling methods to ensure that samples are collected in a proper, consistent, and professionally accepted manner.

13. Health and safety committees and employee suggestion programs address employee involvement in decisions that affect worker health and safety.

14. Auditors prepare for an audit by researching the requirements of a program's components and developing a plan to evaluate compliance. Checklists, including extensive lists for each program component, frequently serve to guide the data collection.

15. An agent characterization involves compiling an inventory of environmental agents and includes a description of their potential adverse health effects.

16. The remaining six components that an industrial hygiene program should address are: hazard recognition, hazard evaluation and exposure assessment, hazard control, employee training and involvement, program evaluation, and documentation.

17. The first step involves making a subjective determination as to whether the exposure to each environmental agent listed for an exposure group is low, moderate, high, or very high relative to an exposure limit. The determination should be made using factors such as the frequency and duration of exposure, estimated exposure level, and the severity of the health effects that could result from exposure. The second step in the process is to monitor the exposures and compare the results against established exposure limits. The potential exposures that were rated very high in the first step should be monitored first, while those that were rated low should be monitored last.

18. A supervisor's responsibilities begin with setting a good example for employees and ensuring that safety and health rules are followed. A supervisor must also ensure that employees receive training in potential safety and health hazards and the control measures associated with their jobs. Ensuring that all necessary personal protective equipment is provided and used and that employees receive all required medical examinations are two additional responsibilities. A supervisor also has the responsibility to report promptly any operation or condition that might present a hazard to employees.

## ANSWERS—Case Study

1. The policy statement included in an industrial hygiene program publicly states the following:
   - the company's commitment to employee health and safety
   - the purpose of the program and the requirement for the active participation of all employees
   - the importance that management places on the health and safety of its employees, as well as management's commitment to occupational safety and health. (This commitment is demonstrated by management placing health and safety at the same level of authority and accountability as production.)
   - the company's pledge to comply with all federal, state, and local occupational safety and health regulations
   - a call for active leadership, direct participation, and the enthusiastic support of the entire organization

2. Training is an effective control measure because it provides employees with real-time under-

standing of the potential hazards in the workplace and the corrective actions to be taken to prevent adverse effects.

3. Training methods depend on the type and degree of the hazard, both of which should be determined by an industrial hygienist.

4. In terms of requirements for training programs, OSHA recommends beginning by determining whether training can solve a problem. Training can address lack of knowledge or incorrect knowledge, but cannot effectively address lack of motivation or attention to the job. It is also important to determine what is expected of an employee and what kind of training is needed to accomplish this goal. It may help to consult with the safety and health committee to hear its suggestions for tailoring training to employees' needs. OSHA also recommends that clear, measurable instructional objectives written in specific, action-oriented language be established before training begins. Training sessions should simulate the actual job as closely as possible using participatory techniques such as hands-on work or case studies. The training should be presented so that its organization and meaning are clear to employees. An effective program enables employees to demonstrate they have acquired the necessary skills and knowledge. To ensure a training program is accomplishing its goals, OSHA requires that an evaluation be done using student surveys, a supervisor's observations, or tests. If any aspect of a training program is unsuccessful, it needs to be revised and those steps of the process repeated. To document how training needs have been met, OSHA suggests using attendance records, course outlines, lesson plans, student exams, and handout materials.

# Chapter 28
# Government Regulations

## ANSWERS—Quiz 1

1. a
2. a
3. b
4. a
5. b
6. d
7. a
8. b
9. d
10. c
11. b

12. Each employer shall furnish to each employee a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm to the employee. Each employer shall comply with occupational safety and health standards under the act. Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to the act that are applicable to his or her own actions and conduct.

13. The significance of the General Duty Provision is that it authorizes the enforcement of a recognized industry safety or health standard when identified hazards are not covered by an existing OSHA standard.

14. As provided for under section 18 of OSHAct, a state agency can assert jurisdiction under state law over safety and health if a state plan that meets the criteria set forth in section 18(c) is submitted for approval by federal OSHA. As of this date, there are 23 approved state plans as well as plans for Puerto Rico and the Virgin Islands.

15. The OSHA standards consist of the following categories: design standards, performance standards, vertical standards, and horizontal standards.

16. In 1976, OSHA defined the action level as typically one-half the permissible exposure limit (PEL). Where exposures reach or exceed the action level, additional requirements apply, including medical surveillance and a full air-monitoring program. Exposures to an airborne concentration above the PEL trigger still further requirements, including reduction of exposures

to or below the PEL by means of engineering controls supplemented by work practice controls, use of specified respirators, and use of other appropriate protective clothing and equipment.

17. The essential elements of a visit are preinspection planning, opening conference, walk-through inspection, sample collection, and closing conference.

18. A failure to abate situation exists when an item of equipment or condition previously cited has never been brought into compliance and is noted at a later inspection.

19. The standard requires the following employee training measures:
    - explanation of the requirements of the standard
    - identification of workplace operations where hazardous chemicals are present
    - knowledge of the methods and observations used to detect the presence of hazardous workplace chemicals.
    - assessment of the physical and health hazards of those chemicals
    - warnings about hazards associated with chemicals in unlabeled pipes.
    - descriptions of hazards associated with nonroutine tasks
    - details about the measures employees can take to protect themselves against these hazards, including specific procedures.
    - explanation of the labeling system
    - instructions on location and use of material safety data sheets (MSDSs)
    - details on the availability and location of the hazardous material inventory, MSDSs, and other written hazard communications material.

20. The student should demonstrate a complete understanding of the role of the secretary of labor as outlined in the text. In summary, the OSHAct grants the secretary of labor the authority to promulgate, modify, and revoke safety and health standards; to conduct inspections and investigations and to issue citations, including proposed penalties; to require employers to keep records of safety and health data; to petition the courts to restrain imminent danger situations; and to approve or reject plans from states proposing to assume jurisdiction from federal OSHA over their private sector industries and state and local governments. The act authorizes the secretary to have the Department of Labor train personnel in the duties related to their responsibilities under the act and, in consultation with the U.S. Department of Health and Human services, to provide training and education to employers and employees. The secretary may grant funds to the states to identify program needs and plan development, experiments, demonstrations, administration/operation of programs. Along with the Department of Health and Human Services, the secretary of labor is charged with developing and maintaining a statistics program for occupational safety and health

## ANSWERS—Quiz 2

1. b
2. b
3. b
4. a
5. a
6. c
7. a
8. c
9. d
10. b
11. c

12. It has been determined that three key duties should be triggered when an action level is reached—exposure measurement, medical surveillance, and employee training. All three actions are considered necessary by OSHA before employee exposures reach the PEL.

13. Getting Results and Improving Performance (GRIP) focuses on achieving the following objectives:
    - reducing injuries, illnesses, death
    - increasing assistance provided to employers and employees in providing safe and health-

ful workplaces
- addressing problems before they may result in workplace incidents
- concentrating limited resources on the worst hazards and workplaces
- delivering better public service in a more prompt and efficient manner
- creating a better place for OSHA field staff to work by building joint labor-management consensus

14. The student will most likely name the broad categories of Monitoring Program, Medical Program, Education and Training Programs, and Record-Keeping Program. Also give credit if he/she names specifics of these programs, i.e., even if a student does not specifically say "Record-Keeping Program," give credit if they mention something about how long records are maintained or the accessibility of records to employees.

15. Regulated areas must be clearly identified and known to affected employees. Regulated areas shall be demarcated and segregated from the rest of the workplace in a manner that minimizes the number of people who will be exposed to a chemical. The regulated area designations must be maintained according to the criteria of the standard. Daily rosters of authorized personnel entering and leaving the area must be maintained. Summaries of such rosters are acceptable.

16. The student must name one of the following criteria:
    - The violations resulted in a worker fatality, a worksite catastrophe, or a large number of illnesses.
    - The violations resulted in persistently high rates of worker injuries or illnesses.
    - The employer has an extensive history of prior violations of the act.
    - The employer has intentionally disregarded its safety and health responsibilities.
    - The employer's conduct taken as a whole amounts to clear bad faith in the performance of his or her duties under the act.
    - The employer has committed a large number of violations so as to undermine significantly the effectiveness of any safety and health program in place.

17. An "other than serious violation" is one that has a direct relationship to job safety and health but probably would not cause death or serious physical harm, such as a tripping hazard.

18. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) established the Superfund Program to handle emergencies at uncontrolled waste sites, to clean up the sites, and to deal with related problems.

19. The student essay should summarize the following information:
    - The main purpose of the walk-through inspection is to identify potential workplace health hazards.
    - During the walk-through, the industrial hygienist becomes familiar with work processes, collects information on chemical and physical agents, and observes workers' activities.
    - The industrial hygienist obtains information concerning raw materials used, intermediates (if any), and final products.
    - The hygienist requests a list of raw materials received at the loading dock.
    - He also checks for hazardous physical agents present in the facility such as noise and excessive heat.
    - He observes work activity throughout the facility, but concentrates particularly on potential health hazard areas.
    - The approximate number of workers in each area is written on the sketch of the facility.
    - The hygienist observes and records the general mobility of the workers and indicates whether they are engaged in stationary or transient activities.
    - Existing engineering controls are marked.
    - Ventilation measurements are made at strategic locations.
    - The hygienist keeps alert for any imminent dangers.
    - Photographs and employee interviews are encouraged.

20. The student should demonstrate an understanding of the broad scope of the OSHAct, touching upon many of the following key provisions:
    - Assure, insofar as possible, that every employee has safe and healthful working conditions.
    - Require employers to maintain accurate records of exposures to potentially toxic mate-

rials or harmful physical agents that are required, under the various safety and health standards, to be monitored or measured, and inform employees of the monitoring results.
- Provide for employee walkaround or interview of employees during the inspection process.
- Provide procedures for investigating alleged violations at the request of any employee or employee representative, issuing citations, and assessing monetary penalties against employers.
- Empower the secretary of labor (through the Occupational Safety and Health Administration) to issue safety and health regulations and standards that have the force and effect of law.
- Provide for establishment of new rules and regulations for new or anticipated hazards to health and safety.
- Establish a National Institute for Occupational Safety and Health (NIOSH), with the same right of entry as OSHA representatives, to undertake health studies of alleged hazardous conditions and to develop criteria to support revisions of health standards or recommendations to OSHA for new health standards.
- Provide up to 50/50 funding with states that wish to establish state programs that are at least as effective as the federal program in providing safe and healthful employment.
- Provide funds to state governments and other entities for the purpose of authorizing and enabling them to conduct onsite consultations for employers upon request.

## ANSWERS—Case Study

1. The essential elements of a visit are preinspection planning, opening conference, walk-through inspection, sample collection, and closing conference.

2. Ms. Greenley would like to examine the facility's monitoring program, medical program, education and training programs, and record-keeping programs.

3. The main purpose of the walk-through inspection is to identify potential workplace health hazards; during the walk-through, the industrial hygienist becomes familiar with work processes, collects information on chemical and physical agents, and observes workers' activities. The industrial hygienist obtains information concerning raw materials used, intermediates (if any), and final products. The hygienist requests a list of raw materials received at the loading dock. He also checks for hazardous physical agents present in the facility such as noise and excessive heat. He observes work activity throughout the facility, but concentrates particularly on potential health hazard areas. The approximate number of workers in each area is written on the sketch of the facility. The hygienist observes and records the general mobility of the workers and indicates whether they are engaged in stationary or transient activities. Existing engineering controls are marked. Ventilation measurements are made at strategic locations. The hygienist keeps alert for any imminent dangers. Photographs and employee interviews are encouraged.

4. An industrial hygienist makes sure that regulated areas meet the following standards: They must be clearly identified and known to affected employees. Regulated areas shall be demarcated and segregated from the rest of the workplace in a manner that minimizes the number of people who will be exposed to a chemical. The regulated area designations must be maintained according to the criteria of the standard. Daily rosters of authorized personnel entering and leaving the area must be maintained. Summaries of such rosters are acceptable.

5. Types of violations include the following: imminent danger, serious violations, and willful violations. In addition, there are criminal/willful violations, repeated violations, egregious conditions, and other-than-serious violations.

# Chapter 29
# History of the Federal Occupational Safety and Health Administration

## ANSWERS—Quiz 1

1. b

2. a

3. b

4. a

5. a

6. d

7. b

8. c

9. The Occupational Safety and Health Act was signed into law on December 29, 1970.

10. The disagreement over the proposed creation of OSHA centered on the extent of the powers to be assigned to the secretary of labor. Generally, Democrats favored a strong role for the secretary, while the Republicans felt the concentration would not be balanced with a strong role.

11. Two elements in the statutory structure are designed to constitute an incentive to employers to abate hazards: (1) sanctions are imposed when violations are disclosed at the first inspection, and (2) no advance notice is given of workplace inspections.

12. The Bureau of Labor Statistics in the Department of Labor was assigned the responsibility of developing an effective program of collection, compilation, can analysis of occupational safety and health statistics.

13. George C. Guenther was the first head of OSHA, its first assistant secretary.

14. An administrative structure was established for OSHA that included 10 regional offices and 49 area offices staffed with compliance officers responsible for conducting workplace inspections.

15. In 1969, several factors contributed to a consensus that federal occupational legislation was needed, including: (1) the workers' compensation system had not provided sufficient financial incentives for employers to improve workplace safety and health; (2) the accident rate was rising; (3) illness in the workplace was a serious and rapidly increasing problem; and (4) state efforts had proven inadequate.

16. To the extent that a hazard is not covered by a standard, the employer must comply with the general duty obligation to provide a workplace free from recognized hazards likely to cause death or serious physical harm."

17. OSHA's first priority for inspection (after dealing with imminent dangers) is to investigate workplaces where fatalities or catastrophes have occurred; the second priority is response to employee complaints; the third priority is the special hazard elimination programs, which include target industries and health hazards; and the fourth priority, to the extent resources are available, is to conduct inspections of all other workplaces to show that the act's obligations are applicable to all.

## ANSWERS—Quiz 2

1. b

2. a

3. a

4. b

5. a

6. d

7. Many of OSHA's start-up standards were taken from standards issued by the American National Standards Institute (ANSI) and the National Fire Protection Association (NFPA).

8. The right of employees or their representatives to request an inspection and their right to participate in the physical inspection of the workplace are foremost in the OSHA program.

9. The source of Congress's influence over OSHA is its ultimate authority to amend the OSHAct and, on a continuing basis, its power to control the agency's annual appropriations.

10. A lead standard issued in 1978 contained a novel provision requiring employers to transfer employees who were at excess risk from lead

exposure to lower-exposure jobs, and to maintain their wage levels and seniority, generally for a period of up to 18 months.

11. Under the OSHAct, criminal penalties can be imposed for willful violations of a standard causing the death of an employee.

12. Two overriding issues have been argued and resolved in standards proceedings: (1) the PEL necessary to protect employees, and (2) the economic and technological feasibility of reaching that level through engineering controls.

13. In September 1974, OSHA received a complaint from a former employee of Life Sciences Products Company, a chemical manufacturer, alleging his exposure to pesticide fumes and dust. Because of the complaint's informality, the OSHA office did not conduct an inspection. About 10 months later, it became known that Life Sciences employees had been massively exposed to Kepone, a pesticide that caused serious illness in seven employees. It was also discovered that pervasive ecological damage had been caused by the company's unlawful disposal of Kepone in the James river. Soon thereafter OSHA revised its field instructions on inspections.

14. OSHA started the "egregious" penalty policy in 1986, when the agency directed its field staff to impose separate penalties for different instances of violations if the inspection disclosed flagrant and widespread violations at the workplace. Previously, separate instances of the same violation wold be grouped together as one violation.

## ANSWERS—Case Study

1. For several years there had been a significant increase in injuries caused by repetitive motion and other ergonomic-related factors, cutting across a wide spectrum of industries and workplaces.

2. In 1990, OSHA responded to this new and serious problem by establishing a special-emphasis enforcement program for ergonomics. To coordinate and support agency activities in the ergonomics area, OSHA established a new Office of Ergonomic Support in its Technical Support Directorate.

3. In 1992, OSHA published an advance notice of proposed rulemaking, requesting data and comments on ergonomic hazards in the workplace related to the absence of ergonomic safety and health programs. Although OSHA has stated that publication of an ergonomics standard is a high priority, the future of the rulemaking is unclear in view of strong employer opposition and controversy in Congress over the standard.