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<th>Definition</th>
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</thead>
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<tr>
<td>ABIH</td>
<td>American Board of Industrial Hygiene</td>
</tr>
<tr>
<td>ACE</td>
<td>air change effectiveness</td>
</tr>
<tr>
<td>ACFM</td>
<td>actual cubic feet per minute</td>
</tr>
<tr>
<td>ACGIH</td>
<td>American Conference of Governmental Industrial Hygienists</td>
</tr>
<tr>
<td>AIHA</td>
<td>American Industrial Hygiene Association</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigeration, and Air Conditioning Engineers</td>
</tr>
<tr>
<td>ASI</td>
<td>air sampling instruments</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ASSE</td>
<td>American Society of Safety Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>BEI</td>
<td>biological exposure indices</td>
</tr>
<tr>
<td>BLS</td>
<td>Bureau of Labor Statistics</td>
</tr>
<tr>
<td>BDL</td>
<td>biosafety level</td>
</tr>
<tr>
<td>CAIRS</td>
<td>Computerized Accident/Incident Reporting System</td>
</tr>
<tr>
<td>CBD</td>
<td>chronic beryllium disease</td>
</tr>
<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention</td>
</tr>
<tr>
<td>cfm</td>
<td>cubic feet per minute</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>CNS</td>
<td>central nervous system</td>
</tr>
<tr>
<td>COPD</td>
<td>chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>CSF</td>
<td>cerebrospinal fluid</td>
</tr>
<tr>
<td>CTS</td>
<td>carpal tunnel syndrome</td>
</tr>
<tr>
<td>d</td>
<td>density, g/cm³</td>
</tr>
<tr>
<td>dB</td>
<td>decibel</td>
</tr>
<tr>
<td>dBA</td>
<td>A-weighted decibel</td>
</tr>
<tr>
<td>DOE</td>
<td>U.S. Department of Energy</td>
</tr>
<tr>
<td>DOT</td>
<td>U.S. Department of Transportation</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>EWP</td>
<td>enhanced work planning</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>FM</td>
<td>Factory Mutual</td>
</tr>
<tr>
<td>FTF</td>
<td>filter test facility</td>
</tr>
<tr>
<td>GHS</td>
<td>Globally Harmonized System</td>
</tr>
<tr>
<td>GHz</td>
<td>gigahertz</td>
</tr>
<tr>
<td>GN</td>
<td>glomerulonephritis</td>
</tr>
<tr>
<td>HEPA</td>
<td>high-efficiency particulate air (filter)</td>
</tr>
<tr>
<td>HHS</td>
<td>Health and Human Services</td>
</tr>
<tr>
<td>HTO</td>
<td>tritium oxide</td>
</tr>
<tr>
<td>HVAC</td>
<td>heating, ventilation, and air conditioning</td>
</tr>
<tr>
<td>ISM</td>
<td>integrated safety management</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>kcal</td>
<td>kilocalorie</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>kHz</td>
<td>kilohertz</td>
</tr>
<tr>
<td>kPa</td>
<td>kilopascal</td>
</tr>
<tr>
<td>L</td>
<td>liter</td>
</tr>
<tr>
<td>LCL</td>
<td>lower confidence limit</td>
</tr>
<tr>
<td>LFFH</td>
<td>laminar flow fume hoods</td>
</tr>
<tr>
<td>LOD</td>
<td>lower limit of detection</td>
</tr>
<tr>
<td>LQAP</td>
<td>Laboratory Quality Assurance Programs</td>
</tr>
<tr>
<td>m</td>
<td>meter</td>
</tr>
<tr>
<td>MERV</td>
<td>minimum efficiency reporting value</td>
</tr>
<tr>
<td>mg</td>
<td>milligram</td>
</tr>
<tr>
<td>min</td>
<td>minute</td>
</tr>
<tr>
<td>mL</td>
<td>milliliter</td>
</tr>
<tr>
<td>mph</td>
<td>miles per hour</td>
</tr>
<tr>
<td>MRP</td>
<td>medical removal protection</td>
</tr>
<tr>
<td>MSD</td>
<td>musculoskeletal disorders</td>
</tr>
<tr>
<td>MSDS</td>
<td>material safety data sheet</td>
</tr>
<tr>
<td>MSHA</td>
<td>Mine Safety and Health Administration</td>
</tr>
<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
</tr>
<tr>
<td>NIH</td>
<td>National Institutes of Health</td>
</tr>
<tr>
<td>NIOSH</td>
<td>National Institute for Occupational Safety and Health</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>NLCP</td>
<td>National Laboratory Certification Program</td>
</tr>
<tr>
<td>NLTN</td>
<td>National Laboratory Training Network</td>
</tr>
<tr>
<td>nm</td>
<td>nanometer</td>
</tr>
<tr>
<td>NNSA</td>
<td>National Nuclear Security Administration</td>
</tr>
<tr>
<td>OA</td>
<td>outside air</td>
</tr>
<tr>
<td>OMB</td>
<td>Office of Management and Budget</td>
</tr>
<tr>
<td>ORBITT</td>
<td>Occurrence Reporting Binned Information Trending Tool</td>
</tr>
<tr>
<td>ORPS</td>
<td>Occurrence Reporting and Processing System</td>
</tr>
<tr>
<td>OSH</td>
<td>occupational safety and health</td>
</tr>
<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
</tr>
<tr>
<td>PAA</td>
<td>personal apparel assessment</td>
</tr>
<tr>
<td>PEL</td>
<td>permissible exposure limit</td>
</tr>
<tr>
<td>PL</td>
<td>Public Law</td>
</tr>
<tr>
<td>PPE</td>
<td>personal protective equipment</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
</tr>
<tr>
<td>PSE</td>
<td>particle size efficiency</td>
</tr>
<tr>
<td>PT</td>
<td>performance testing</td>
</tr>
<tr>
<td>PVC</td>
<td>polyvinyl chloride</td>
</tr>
<tr>
<td>QA</td>
<td>quality assurance</td>
</tr>
<tr>
<td>QPL</td>
<td>quality product list</td>
</tr>
<tr>
<td>RF</td>
<td>radio frequency</td>
</tr>
<tr>
<td>RSI</td>
<td>repetitive stress injury</td>
</tr>
<tr>
<td>Acronyms</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>SCBA</td>
<td>self-contained breathing apparatus</td>
</tr>
<tr>
<td>SOMD</td>
<td>site occupational medical director</td>
</tr>
<tr>
<td>spp</td>
<td>species (plural or group)</td>
</tr>
<tr>
<td>SSCs</td>
<td>structures, systems, and components</td>
</tr>
<tr>
<td>STEL</td>
<td>short-term exposure limit</td>
</tr>
<tr>
<td>μm</td>
<td>second microgram</td>
</tr>
<tr>
<td>TAC</td>
<td>task/ambient conditioning</td>
</tr>
<tr>
<td>TLV</td>
<td>threshold limit value</td>
</tr>
<tr>
<td>TWA</td>
<td>time-weighted average</td>
</tr>
<tr>
<td>UFAD</td>
<td>under-floor air distribution</td>
</tr>
<tr>
<td>UCL</td>
<td>upper confidence limit</td>
</tr>
<tr>
<td>UL</td>
<td>Underwriters Laboratories</td>
</tr>
<tr>
<td>WBGT</td>
<td>wet bulb globe temperature</td>
</tr>
</tbody>
</table>
PURPOSE
The purpose of this reference guide is to provide a document that contains the information required for a Department of Energy (DOE)/National Nuclear Security Administration (NNSA) technical employee to successfully complete the Industrial Hygiene Functional Area Qualification Standard (FAQS). Information essential to meeting the qualification requirements is provided; however, some competency statements require extensive knowledge or skill development. Reproducing all the required information for those statements in this document is not practical. In those instances, references are included to guide the candidate to additional resources.

SCOPE

Please direct your questions or comments related to this document to the NNSA Learning and Career Development Department.

PREFACE
Competency statements and supporting knowledge and/or skill statements from the qualification standard are shown in contrasting bold type, while the corresponding information associated with each statement is provided below it.

A comprehensive list of acronyms and abbreviations is found at the beginning of this document. It is recommended that the candidate review the list prior to proceeding with the competencies, as the acronyms and abbreviations may not be further defined within the text unless special emphasis is required.

The competencies and supporting knowledge, skill, and ability (KSA) statements are taken directly from the FAQS. Most corrections to spelling, punctuation, and grammar have been made without remark, and all document-related titles, which variously appear in roman or italic type or set within quotation marks, have been changed to plain text, also mostly without remark. Capitalized terms are found as such in the qualification standard and remain so in this reference guide. When they are needed for clarification, explanations are enclosed in brackets.

Every effort has been made to provide the most current information and references available as of December 2009. However, the candidate is advised to verify the applicability of the information provided. It is recognized that some personnel may oversee facilities that utilize predecessor documents to those identified. In those cases, such documents should be included in local qualification standards via the Technical Qualification Program.
In the cases where information about an FAQS topic in a competency or KSA statement is not available in the newest edition of a standard (consensus or industry), an older version is referenced. These references are noted in the text and in the bibliography.

Only significant corrections to errors in the technical content of the discussion text source material are identified. Editorial changes that do not affect the technical content (e.g., grammatical or spelling corrections, and changes to style) appear without remark.
TECHNICAL COMPETENCIES

1. Industrial hygiene personnel shall demonstrate an expert level knowledge of health stressors that may be found in the workplace and the community.
   
a. Discuss the following types of health stressors and provide examples of hazards that may be anticipated:
   - Chemical
   - Biological
   - Physical

Chemical
The following is taken from the National Safety Council, Fundamentals of Industrial Hygiene.

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

To recognize occupational factors or stresses, a health and safety professional must first know about the chemicals used as raw materials and the nature of the products and by-products manufactured. This sometimes requires great effort. The required information can be obtained from the material safety data sheet (MSDS) that must be supplied by the chemical manufacturer or importer for all hazardous materials under the Occupational Safety and Health Administration (OSHA) hazard communication standard.

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

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

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

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

Biological stressors represent a distinct category of hazards. Unlike chemical or physical hazards, biological stressors (1) grow, reproduce, and die, (2) disperse both actively and passively, (3) interact with other biological populations in the ecosystem, and (4) evolve. Therefore, biological stressors as diverse as human pathogens (e.g., *Salmonella* and *Bacillus anthracis*), plant and animal pathogens (e.g., Asian soybean rust and avian influenza virus), and invasive species (e.g., Mediterranean fruit fly and kudzu) share many common features. The distinction between risk assessment for biological stressors and chemical risk assessment may be overstated, however, and a number of parallels can be drawn. For example, pathogen inactivation is analogous to chemical sequestration, and a population of invasive cells in the body is analogous to a population of invasive species in the environment. To date, however, the practice of risk assessment for biological stressors has not adopted conventions as simplifying assumptions to the extent that they are generally applied in the more mature field of chemical risk assessment. As with risk assessment in other fields, managing the tension between complexity and utility is likely to remain an ongoing challenge for the emerging field of risk assessment for biological stressors.

Title 29 CFR 1910.1030 defines bloodborne pathogens as pathogenic microorganisms that are present in human blood and can cause disease in humans. These pathogens include, but are not limited to, hepatitis B virus and human immunodeficiency virus.

Each employer having an employee(s) with occupational exposure shall establish a written exposure control plan designed to eliminate or minimize employee exposure. Occupational exposure means reasonably anticipated skin, eye, mucous membrane, or parenteral contact with blood or other potentially infectious materials that may result from the performance of an employee’s duties. Each employer who has an employee(s) with occupational exposure shall prepare an exposure determination. Engineering and work practice controls shall be used to eliminate or minimize employee exposure. Where occupational exposure remains after institution of these controls, personal protective equipment (PPE) shall also be used.

When there is occupational exposure, the employer shall provide, at no cost to the employee, appropriate PPE such as, but not limited to, gloves, gowns, and laboratory coats; face shields/masks and eye protection; and mouthpieces, resuscitation bags, pocket masks, or other ventilation devices. PPE will be considered appropriate only if it does not permit blood or other potentially infectious materials to pass through or to reach the employee’s work clothes, street clothes, undergarments, skin, eyes, mouth, or other mucous membranes under normal conditions of use and for the duration of time the protective equipment will be used.

The risk and precautions for level A laboratories are described by agent in table 1.
Table 1. Risk and precautions for level A laboratories

<table>
<thead>
<tr>
<th>Agent</th>
<th>BSL</th>
<th>Specimen Handling</th>
<th>Culture Handling</th>
<th>Specimen Exposure Risk</th>
<th>Recommended Precautions for Level A Laboratories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillus anthracis</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Blood, skin lesion exudates, CSF, pleural fluid sputum, and rarely urine and feces.</td>
<td>BSL2: Activities involving clinical material collection and diagnostic quantities of infectious cultures. BSL3: Activities with high potential for aerosol or droplet production.</td>
</tr>
<tr>
<td>Brucella spp</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>Blood, bone marrow, CSF, tissue, semen and occasionally urine.</td>
<td>BSL2: Activities limited to collection, transport and plating of clinical material. BSL3: All activities involving manipulations of cultures.</td>
</tr>
<tr>
<td>Clostridium botulinum</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Toxin may be present in food specimens, clinical material (serum, gastric and feces), and environmental samples (soil, surface water). Toxin is extremely poisonous.</td>
<td>BSL2: Activities with materials known or potentially containing toxin must be handled in a biological safety cabinet with a lab coat, disposable surgical gloves, and a face shield. BSL3: Activities with high potential for aerosol or droplet production.</td>
</tr>
<tr>
<td>Francisella tularensis</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>Skin lesion exdates, respiratory secretions, CSF, blood, and urine. Tissues from infected animals and fluids from infected arthropods.</td>
<td>BLS2: Activities limited to collection, transport and plating of clinical material. BSL3: All activities involving manipulations of cultures.</td>
</tr>
<tr>
<td>Yersinia pestis</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Bubo fluid, blood, sputum, CSF, feces, and urine.</td>
<td>BSL2: Activities involving clinical material collection and diagnostic quantities of infectious cultures. BSL3: Activities with high potential for aerosol or droplet production.</td>
</tr>
<tr>
<td>Smallpox</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>Lesion fluid or crusts, respiratory secretions, or tissue.</td>
<td>BSL4: Specimen collection/transport</td>
</tr>
<tr>
<td>VHF</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>Blood, urine, respiratory secretions, or semen, and tissue.</td>
<td>BSL4: Specimen collection/transport</td>
</tr>
</tbody>
</table>

Source: CDC Microbiology Biosafety

1. Laboratory-acquired brucellosis has occurred by sniffing cultures; aerosols generated by centrifugation; mouth pipetting; accidental parenteral inoculations; sprays into eyes, nose, and mouth; and by direct contact with clinical specimens.
2. Exposure to toxin is the primary laboratory hazard since absorption can occur with direct contact with skin, eyes, or mucous membranes, including the respiratory tract. The toxic can be neutralized by 0.1 M sodium hydroxide. C. botulinum is inactivated by 1:10 dilution of household bleach. Contact time is 20 minutes. If material contains toxin and organisms, the spill must be sequentially treated with bleach and sodium hydroxide for a total contact time of 40 minutes.

3. Laboratory-acquired tularemia infection has been more commonly associated with cultures than with clinical materials/animals. Direct skin/mucous membrane contact with cultures; parenteral inoculation; ingestion; and aerosol exposure have resulted in infection.

4. Special care should be taken to avoid the generation of aerosols.

5. Ingestion, parenteral inoculation, and droplet or aerosol exposure of mucous membranes or broken skin with infectious fluids or tissues are the primary hazards to laboratorians.

6. Respiratory exposure to infections aerosols, mucous membrane exposure to infectious droplets, and accidental parenteral inoculation are the primary hazards to laboratorians.

**Physical**

Title 29 CFR 1910.95 states that when employees are subjected to sound levels exceeding those listed in table 2, below, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels to permissible limits as specified in table 2, PPE shall be provided and used to reduce sound levels so that they fall within the levels of the table.

<table>
<thead>
<tr>
<th>Duration per day (hours)</th>
<th>Sound level, dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slow Response</td>
</tr>
<tr>
<td>8</td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>95</td>
</tr>
<tr>
<td>3</td>
<td>97</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>1½</td>
<td>102</td>
</tr>
<tr>
<td>1</td>
<td>105</td>
</tr>
<tr>
<td>½</td>
<td>110</td>
</tr>
<tr>
<td>¼ or less</td>
<td>115</td>
</tr>
</tbody>
</table>

*Source: 29 CFR 1910.195*

The employer shall administer a continuing, effective hearing conservation program whenever employee noise exposures equal or exceed an eight-hour time-weighted average sound level of 85 decibels measured on the A scale (slow response) or, equivalently, a dose of 50 percent.

According to 29 CFR 1926.54, employees working in areas where there exists a potential exposure to direct or reflected laser light greater than 0.005 watts (5 milliwatts) shall be provided with anti-laser eye protection devices. Areas in which lasers are used shall be posted with standard laser warning placards. Employees whose occupation or assignment requires exposure to laser beams shall be furnished suitable laser safety goggles which will
protect for the specific wavelength of the laser and be of optical density adequate for the energy involved.

Lasers are classified in categories 1 (safe) to 4 (dangerous). Most precautions apply to Class 3b and 4 lasers. The American Conference of Governmental Industrial Hygienists (ACGIH) provides threshold limit values (TLVs) for lasers, while ANSI Z136.1, *American National Standard for the Safe Use of Lasers*, provides more detailed guidance on acceptable practices to provide safety. DOE O 420.2B, *Safety of Accelerator Facilities*, states that although eye injury from nonionizing radiation is generally the primary hazard, laser systems can present electrical and chemical hazards as well. In addition to the nonionizing radiation hazard, electrical hazards are associated with the high-voltage power supplies used in many laser systems. In particular, Class 4 lasers often use large power supplies that carry an appreciable risk of electrocution, especially in maintenance and adjustment procedures. Chemical hazards can be associated with halogen and dye lasers, as well as with radiation decomposition.

Electromagnetic radiation is restricted to that portion of the spectrum commonly defined as the radio frequency (RF) region, which includes the microwave frequency region. DOE G 420.2-1, *Accelerator Facility Safety Implementation Guide for DOE O 420.2B, Safety of Accelerator Facilities*, states that to avoid exposure of persons to unacceptable levels of RF fields, engineered control measures, such as shielding, prevention of wave guide leakage, enclosures, interlocks preventing accidental energizing of circuits, and dummy load terminations, should be given first consideration over any use of PPE. Where exposure in excess of the limits is possible, RF leakage tests should be conducted when the system is first operated and after modifications that might result in changes to the leakage. Area RF monitors are appropriate when RF energy can be expected in occupied areas. The ACGIH specifies guidelines for personnel protection in the form of TLVs. Use of the ACGIH guidelines in their most current form for RF and microwave fields is required as part of worker protection management for DOE contractor employees.

b. **Describe how the following sources of information can be used to assist in the anticipation of health stressors:**

- Standards
- Regulations
- Standard texts and references
- Material safety data sheet (MSDS) of materials in site inventories

**Standards**

The following is taken from DOE G 252.1-1.

As defined in Public Law (PL) 104-113, technical standards are “performance-based or design-specific technical specifications and related management system practices” that are developed and adopted by voluntary consensus standards bodies. The Office of Management and Budget (OMB), Circular No. A-119 expands the PL 104-113 definition of standards to include (1) common and repeated use of rules, conditions, guidelines, or characteristics for products or related processes and production methods, and related management systems practices; and (2) the definition of terms; classification of components; delineation of procedures; specification of dimensions, materials, performance, designs, or operations;
measurement of quality and quantity in describing materials, processes, products, systems, services, or practices; test methods and sampling procedures; or descriptions of fit and measurements of size or strength.

DOE describes technical standards in a manner similar to OMB A-119; that is, as a prescribed set of criteria concerned with classification of components; delineation of procedures; specification of materials, products, performance, design, or operations; and definitions of terms or measurements of quality and quantity in describing materials, products, systems, services, or practices.

The most common topics for DOE technical standards are related to nuclear technology and environment, safety, and health aspects of nuclear technology, such as design, construction, maintenance, operational standards, performance, management systems, component and facility classification, common practices, and technical specifications. Still others include decommissioning, information management, training, standardized procedures, project management, services, and product specifications.

 Regulations 

The following is taken from the U.S. Department of Labor, OSHA, *Informational Booklet on Industrial Hygiene*.

Under the Occupational Safety and Health (OSH) Act of 1970, OSHA develops and sets mandatory occupational safety and health requirements applicable to the more than 6 million workplaces in the U.S. OSHA relies on, among many others, industrial hygienists to evaluate jobs for potential health hazards. Developing and setting mandatory occupational safety and health standards involves determining the extent of employee exposure to hazards and deciding what is needed to control these hazards, thereby protecting the workers. Industrial hygienists are trained to anticipate, recognize, evaluate, and recommend controls for environmental and physical hazards that can affect the health and well-being of workers. More than 40 percent of the OSHA compliance officers who inspect America’s workplaces are industrial hygienists. Industrial hygienists also play a major role in developing and issuing OSHA standards to protect workers from health hazards associated with toxic chemicals, biological hazards, and harmful physical agents. They also provide technical assistance and support to the agency’s national and regional offices. OSHA also employs industrial hygienists who assist in setting up field enforcement procedures, and who issue technical interpretations of OSHA regulations and standards. Industrial hygienists analyze, identify, and measure workplace hazards or stressors that can cause sickness, impaired health, or significant discomfort in workers through chemical, physical, ergonomic, or biological exposures. Two roles of the OSHA industrial hygienist are to spot those conditions and help eliminate or control them through appropriate measures.

 Standard Texts and References 

The following is taken from the American Industrial Hygiene Association, Health and Safety Standards for Ventilation Systems.
The purpose of AIHA ASC Z9, health and safety standards for ventilation systems is to maintain and update existing standards in the Z9 series, establish new standards as necessary, and resolve issues concerning those standards. The scope of the ASC Z9 encompasses standards for the design, operation and maintenance of equipment to provide a safe atmosphere in industrial, manufacturing or construction operations by removing harmful substances by either local exhaust or general ventilation and safely disposing of such substances, and such supplementary standards on personal protection as may be necessary to prescribe methods for the protection of workers.

This standard establishes minimum control requirements and ventilation system design criteria for controlling and removing air contaminants to protect the health of personnel engaged in open-surface tank operations.

This standard establishes minimum requirements for the commissioning, design, specification, construction, and installation of fixed industrial local exhaust ventilation systems used for the reduction and prevention of employee exposure to harmful airborne substances in the industrial environment.

This standard is intended to help manufacturers and users protect the health of personnel from injurious effects of contact with gases, vapors, mists, dusts, powders, or solvents used in, or created, released or disseminated during or by spray finishing operations.

Z9.5: ANSI/AIHA Z9.5-2003 Laboratory Ventilation
This standard sets forth the requirements for the design and operation of laboratory ventilation systems.

Z9.6: ANSI/AIHA Z9.6-2008 Exhaust Systems for Grinding, Buffing and Polishing
The rules and engineering principles described in this standard represent the minimum criteria intended to protect the health of personnel engaged in and working in the vicinity of grinding, polishing, and buffing operations; and to control contaminants generated by those operations.

This standard established minimum criteria for the design and operation of a re-circulating industrial process exhaust ventilation system used for contaminant control.

Z9.9: BSR/AIHA Z9.9 (Draft) Portable Ventilation Systems
This standard discusses portable ventilation equipment and systems used for the reduction, control or prevention of exposure to hazardous atmospheres or airborne substances in the occupational environment, and for provision of comfort to employees.
This standard establishes minimum requirements for the commissioning, design, specification, construction, installation, management, operation, maintenance and testing of dilution ventilation systems (including demand dilution ventilation) used for the reduction, prevention and control of employee exposure to harmful airborne substances in the industrial environment.

This standard provides an overarching roadmap for the decommissioning process of biological research laboratories that can assist an institution in developing its own decommissioning plan.

BSR - AIHA Z9.12 Design, Operation and Maintenance of Combustible Dust Collection Systems
This standard will apply to dust control systems with combustible solids that are a fire, deflagration, explosion or detonation hazard. This standard will augment the content of other Z9 standards. This standard will offer prudent practice regarding
- analysis of systems for combustible dust hazards
- design guidance to mitigate combustible dust hazards
- maintenance recommendations to insure systems operate per original design intent

This standard will apply to laminar flow fume hoods (LFFH) that use filtered supply air and ducted exhaust to protect products inside the hood from external contamination and exhaust hazardous effluents from the building. This standard will provide guidelines for design, operation, testing and maintenance of laminar flow fume hoods. Laminar flow fume hoods are complicated exposure control devices that must be designed and operated properly to provide both product and personnel protection. At present, there are no standards that provide guidelines for design, operation and testing. As such, there is little consistency between LFFHs and how they operate. In addition, there is no guidance on methods to conduct tests to ensure proper performance or monitor and maintain reliable operation. This standard will provide the necessary guidelines to improve performance of LFFHs and ensure better protection for personnel working with potentially hazardous materials.

The following is taken from ANSI/AIHA Z88 Accredited Standards Committee, Respiratory Protection
The purpose of the Z88 committee is to maintain and update existing standards in the Z88 series, establish new standards as necessary, and resolve issues concerning those standards. The scope of the Z88 committee is to develop safe practices and requirements for using respirators for the protection of the respiratory system from the inhalation of particulate matter, oxygen deficiencies, noxious gases and vapors as well as programs, practices, procedures and equipment related to industrial respiratory protection.
ANSI/AIHA Z88.6 2006 Respirator - Physical Qualifications for Personnel
This standard provides information and guidance to physicians or other licensed health care professionals to assist them in determining the medical suitability of personnel for respirator use.

ANSI/AIHA Z88.7 2001 Color Coding of Air-Purifying Respirator Canisters, Cartridges and Filters
This standard establishes a system of marking air-purifying respirator canisters, cartridges and filters by means of colors in order to facilitate rapid identification of the canisters, cartridges and filters by users, and ensure color consistency among respirator manufacturers.

ANSI/AIHA Z88.10 2001 Respirator Fit Testing Methods
This standard provides guidance on how to conduct fit testing of tight fitting respirators and appropriate methods to be used. Fit testing is only one element of a complete respiratory protection program.

BSR AIHA Z88.12 (Draft) Respiratory Protection for Infectious Aerosols
This new standard will set forth accepted practices for respirator users; provides information and guidance on the proper selection, use, and care of respirators; and contains requirements for establishing and regulating respirator programs.

BSR AIHA Z88.14 (Draft) Respirator Use for Emergency Response and Operations Against Terrorism and Weapons of Mass Destruction
This standard sets forth accepted practices for chemical, biological, radiological, and nuclear (CBRN) respirator use; provides information and guidance on the proper selection, use, and care of respirators; and contains requirements for establishing and regulating respirator programs that would cover the use of respirators to protect persons against the inhalation of harmful air contaminants (including oxygen-deficient atmospheres, by reference) in situations or operations involving emergency use of CBRN respirators in support of domestic preparedness and counterterrorism.

Material Safety Data Sheet (MSDS) of Materials in Site Inventories
The following is taken from 29 CFR 1910.1200.

Material safety data sheets may be kept in any form, including operating procedures, and may be designed to cover groups of hazardous chemicals in a work area where it may be more appropriate to address the hazards of a process rather than individual hazardous chemicals. However, the employer shall ensure that in all cases the required information is provided for each hazardous chemical, and is readily accessible during each work shift to employees when they are in their work area(s).

Material safety data sheets shall also be made readily available, upon request, to designated representatives and to the Assistant Secretary, according to the requirements of 29 CFR 1910.20(e). The Director shall also be given access to material safety data sheets in the same manner.
2. Industrial hygiene personnel shall demonstrate an expert level of knowledge and the ability to anticipate and minimize exposure to health stressors during the planning and design phases of a work activity or from an operational description.

a. Discuss how a review of the following can be used to anticipate and minimize exposure to potential health stressors:
   - Standard texts and references
   - Process/activity raw materials
   - A description of process chemical reactions
   - Process/activity products and by-products
   - Process/activity equipment
   - Process/activity operating procedures

Standard Texts and References
The following is taken from DOE-STD-6005-2001.

To promote the integration of worker protection efforts, the following groups or information resources should be consulted/utilized when planning industrial hygiene evaluations and/or considering exposure controls:
   - Other worker protection staff (e.g., industrial safety professionals, health physicists)
   - Occupation medical staff
   - Environmental protection staff
   - Line management
   - Workers and worker representatives
   - Existing chemical and hazard inventories
   - Applicable written worker protection programs such as respiratory, hazard communication, ergonomics, lead, beryllium, confined space, and hearing conservation
   - Injury and illness logs/databases and trending tools such as the Computerized Accident/Incident Reporting System (CAIRS) and the Occurrence Reporting Binned Information Trending Tool (ORBITT)/ Occurrence Reporting and Processing System (ORPS).

Coordination with Planning and Design Staff
DOE and contractor line management are required to coordinate planning and design activities with industrial hygiene personnel to anticipate and control health hazards that proposed facilities and/or operations would introduce.

DOE O 440.1B, Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees, states that the following elements should be included in industrial hygiene programs:
   - Initial or baseline surveys of all work areas or operations to identify and evaluate potential worker health risks.
   - Coordination with planning and design personnel to anticipate and control health hazards that proposed facilities and operations would introduce.
   - Coordination with cognizant occupational medical, environmental, health physics, and work planning professionals.
• Policies and procedures to mitigate the risk from identified and potential occupational carcinogens.
• Professionally and technically qualified industrial hygienists to manage and implement the industrial hygiene program.
• Periodic resurveys and/or exposure monitoring as appropriate.
• Documented exposure assessment for chemical, physical and biological agents and ergonomic stressors using recognized exposure assessment methodologies and use of accredited industrial hygiene laboratories.
• Specification of appropriate engineering, administrative, work practice, and/or personal protective control methods to limit hazardous exposures to acceptable levels.
• Worker education, training, and involvement.
• Use of appropriate industrial hygiene standards.
• Use of respiratory protection equipment tested under the DOE Respirator Acceptance Program for Supplied-air Suits when National Institute for Occupational Safety and Health approved respiratory protection does not exist for DOE tasks that require such equipment. For security operations conducted in accordance with Presidential Decision Directive 39, U. S. Policy on Counter Terrorism, use of Department of Defense military type masks for respiratory protection by security is acceptable.

For hazards identified either in the facility design or during the development of procedures, controls must be incorporated in the appropriate facility design or procedure.

Conceptual Design Phase

Review at the conceptual design phase, the earliest phase of the project, is critical. This is the phase when line management will most benefit from industrial hygiene input and when the role of the industrial hygienist in the process is most easily established. Specific design questions to be answered include
• To what extent can a system be designed to require minimum maintenance to minimize exposures to maintenance personnel?
• To what extent can the process be conducted in a closed system to minimize exposures to workers and others in the vicinity?
• Can the process be operated automatically or remotely to minimize worker contact with the hazard?
• Can the system be designed in an ergonomically appropriate manner?
• Can the process be designed to make use of less hazardous materials?
• How can the process be designed to employ the best available control technology for capturing and properly disposing of hazardous materials and minimizing pollution?

Design and Development Phase

According to DOE G 440.1-1A, for hazards identified either in the facility design or during the development of procedures, controls are incorporated in the appropriate facility design or procedure.

Hazards that are identified in the design phase of new facilities and facility modifications or during the development or modification of procedures should be eliminated or controlled
through design or procedure changes. The controls implemented should be commensurate with the risk level identified in the risk assessment process. For example, hazards that pose a serious threat to employee health and safety should be either completely eliminated or be effectively controlled.

Proposed design or procedure modifications intended to eliminate or control hazards should be reviewed by worker protection professionals to ensure that the change adequately addresses the hazard and does not introduce new workplace hazards. Alternative control measures should be evaluated to determine the reduction of risk provided by each measure and identify the most effective practical control for the hazard.

When engineering controls do not reduce the associated risk to acceptable levels, they may be supplemented with work practices and administrative controls. Where necessary, these controls may be further supplemented with the use appropriate personal protective equipment.

Coordination of Construction and M&O Safety and Health Requirements

DOE O 440.1B, requires DOE to review safety and health program elements developed by the host for site maintenance and operation activities to determine suitability and cost effectiveness on site construction projects. The intent of this requirement is twofold. First, in instances where the host and construction contractors mutually expose their employees to common hazards, it is probably desirable and cost effective to mandate construction contractor adherence to sitewide OSH policies and procedures. However, there are also instances where mandated compliance by the construction contractor with host OSH program requirements that go beyond applicable DOE adopted OSH standards or are poorly suited to construction will have little, if any, positive impact on safety and health but will adversely affect project cost and schedule.

Hazard Analyses

According to DOE G 440.1-2, Construction Safety Management Guide for Use With DOE Order 440.1, the intent of the required hazard analyses is to compel a proactive and systematic evaluation of project hazards, timely planning of abatement strategies, and effective, relevant employee training. This may be achieved in a variety of ways. Contract provisions may call for a complete hazard evaluation process to be performed by the construction contractor, or the project specifications may provide checklists or outlines that fulfill any portion (or all) of the hazard analysis requirements for later completion and implementation by the construction contractor.

Regardless of the procedural means chosen, a means to identify project operations requiring hazard analyses must be provided prior to project commencement. This ensures a means to “tie” those operations to the project schedule, allowing for their timely completion and providing a means for the project manager to assess whether adequate preparations have been made prior to commencement of each project phase.
The complexity and degree of effort associated with the development of these hazard analyses should not be confused with that required for the preparation of documented safety analyses.

As is common across the construction industry, these analyses commonly require from several lines to several pages for each project operation, depending on the nature of work being addressed. Complexity is not the key; what is essential is the identification and approval, in advance, of the actual work practices and protective measures to be employed. This helps to ensure a safe work environment from the outset on each construction operation and to avoid the often lengthy and costly disputes that occur as a job is delayed while unresolved safety issues are resolved.

By virtue of the fact that the approval authority for these analyses is the project manager or his or her designee, the format, level of detail, and required complexity are left to his or her discretion. However, it may be desirable within local implementing instructions to formalize the procedural means for accomplishing these hazard analyses, including such issues as format and level of required detail.

DOE O 440.1B requires that DOE and its contractors

“analyze and review designs for new facilities and for modifications to existing facilities and equipment; operations and procedures; and equipment, product, and service needs”

and

“implement a hazard prevention/abatement process to ensure that all identified hazards are managed through final abatement or control.”

Department of Energy Acquisition Regulations require the contractor to “ensure that management of environment, safety and health (ES&H) functions and activities becomes an integral but visible part of the contractor’s work planning and execution process”.

Early integration of exposure assessment with work planning activities will help to ensure that potential exposures associated with the work are addressed in the work plan. The use of a multidisciplinary team in planning work will help facilitate this integration. This team, convened at the earliest stage of a job or project, can effectively plan the work to be done and include the hazard characterization and exposure assessment to be performed as part of the job. Team members should include planners, engineers, managers, health and safety professionals, occupational medicine staff, professionals from other technical disciplines, technicians, and representative workers. The DOE enhanced work planning (EWP) initiative is an example of how this aspect may be implemented and how this may fulfill the guiding principles of integrated safety management. For more information on EWP, visit the EWP worldwide web site on the Office of Environment, Safety and Health home page.

According to DOE G 440.1-4, Contractor Occupational Medical Program Guide for Use with DOE Order 440.1, occupational medical physicians, nurses, and selected medical staff
should maintain an ongoing familiarity and awareness of existing or potential work-related health hazards, employee job tasks, and worksite environments.

Close cooperation and coordination with industrial hygiene, health physics, and safety professionals is suggested for the purpose of reviewing materials, processes, and procedures with an emphasis on physical, chemical, and biological hazards present in the worksite.

Regular worksite visits should be conducted by physicians and selected medical staff and, when appropriate, coordinated with industrial hygiene, safety, and health physics for the purpose of becoming knowledgeable and familiar with the work environment and potential hazards.

Contractor management should routinely furnish the physician responsible for medical services with information on potential physical, chemical, and biological hazards at the worksite. This information is necessary to plan for worker protection programs, medical surveillance examinations, emergency planning, and staff training.

Prior to the performance of a periodic health evaluation, contractor management should provide to the occupational health examiner a summary of potential exposures to hazardous agents or tasks and all worksite exposures in excess of the OSHA/DOE permissible exposure limits pertaining to the employee to be evaluated.

Initial Design Phase
Proper initial design is the most cost-effective way to control hazards. The industrial hygiene staff should participate with line management in:

- Planning and design of new processes and/or use of new materials
- Planning and reviewing plans for new construction, demolition, modification, or remodeling of existing processes
- Evaluations of the effectiveness of proposed environmental control equipment
- Approval of procedures for use of control equipment
- Approval of new operations and maintenance procedures

Industrial hygiene design/plan reviews should solicit and include input from affected organizations, professional and technical disciplines, and supervisors and workers knowledgeable about and/or impacted by the new operations and/or materials.

Professional/technical disciplines may include occupational medicine, epidemiology, ergonomics, occupational safety, audiology, fire protection, radiation protection, environmental protection, facility maintenance, operations, and engineering.
The following definitions are taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

**Process/Activity Raw Materials**
A review of the raw materials involved in a process will identify any chemical hazards that are known to exist. Also, if the raw materials come in large quantities, industrial health personnel can ensure that stressors involving physical or ergonomic issues are addressed.

**A Description of Process Chemical Reactions**
Reactions among chemicals vary depending on the processes involved. The greatest short-term health stressors caused by chemical reactions are the production of large quantities of heat or poisonous gas and the possibility of an explosion. Latent stressors could be caused by the creation of carcinogens or other known chemicals that could have long-term, slow-acting effects on the worker. A review and understanding of the chemicals to be used can determine the required PPE that should be available and used. Also, knowing the effects of the chemicals enables management to create engineering controls to prevent or minimize potential health stressors.

**Process/Activity Products and By-products**
Determining the products and by-products of a process allows for the development of safety procedures. Understanding the health hazards that exist from the by-products of materials allows for proper disposal and minimization of health effects to people working with the materials. Also, determining the final by-product of a process will allow for the required safety systems to be put into place for storage and movement of material.

**Process/Activity Equipment**
DOE G 420.1-1, *Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria Guide for Use with DOE O 420.1, Facility Safety*, states that building layouts should provide protection from the hazards associated with handling, processing, and storing of radioactive and/or hazardous materials.

The arrangement and location of hazardous process equipment and the equipment’s maintenance provisions should provide appropriate protective and safety measures. The usual safety function of process equipment is to provide primary confinement and prevent or mitigate radioactive and/or hazardous material releases to the environment. Process equipment that would be required to provide primary confinement includes the following: piping, tanks, pressure vessels, pumps, valves, and gloveboxes. These examples represent process system components that could be used to contain radioactive or toxic materials directly. Process equipment for some applications can provide secondary confinement. Examples include double-walled piping systems, double-walled tanks, and gloveboxes.

Safety-class and safety-significant process equipment providing passive confinement (piping, tanks, holding vessels, etc.) must be designed to suitably conservative criteria. The redundancy criteria described in section 5.1.1.2 of DOE G 420.1-1 must be applied to the design of safety-class structures, systems, and components (SSCs) that involve active confinement process equipment (pumps, valves, etc.). Redundancy criteria should also be
considered in the design of safety-significant SSCs that involve active confinement process equipment.

Process/Activity Operating Procedures
The following is taken from the National Safety Council, Fundamentals of Industrial Hygiene.

Exposure to health stressors may be anticipated from plans wherever materials are added to or removed from an otherwise enclosed system. The need for the addition to, or sampling from, the process might be indicated on plans by the presence of enclosures or local exhaust at these locations. The presence in the plans of control booths for operators might indicate that the designer anticipates noise and heat to be generated from the process.

Process information should contain a list of chemical ingredients and products and information about where and how ingredients would be added. The chemical ingredient and product information should allow a prediction about what stressors are within the system. However, they cannot predict how much of a chemical could escape at the points where chemicals are added, products/wastes are removed, or process samples are taken, or through fugitive emissions.

b. In planning a work activity, recognize the potential ergonomic hazards that may result from the following:
   - Configuration, design, and use of workplace equipment and tools
   - Repetitive motion tasks
   - Work/rest cycle
   - Temperature and other environmental extremes

Configuration, Design and Use of Workplace Equipment and Tools
The following is taken from Manufacturing Engineering, Seven Key Factors for Ergonomic Workstation Design.

It is not always possible or even desirable to automate an assembly task. Assembly operations that are too technologically difficult to automate, products with relatively short life cycles, production of highly customized products, and the need for flexibility to cope with changing production requirements are just a few factors that may dictate the use of manual assembly. In addition, the need to balance the cost of an automated system against its potentially short life cycle makes automation a second choice to manual assembly.

In manual assembly operations, such seemingly minor factors as working surfaces that are slightly too high or low, parts that are positioned slightly beyond the reach of employees, or inadequate lighting can have a serious impact on worker productivity and safety. Ergonomics, the study of human capability, form, and physiology as it relates to the working environment, can minimize barriers to quality, safety, and productivity by fitting products, tasks, and work environments to the people who must use them. This section will outline seven basic rules that govern ergonomic design for workstations.
Worker Size

The size of workers is a very basic factor in ergonomic workstation design. Ergonomic workplaces are designed to fit 90 percent of male and female body sizes, so an ergonomically designed workplace is suitable for just about everybody. When selecting workstation height, process designers should observe several rules.

In any workstation, the height of the work surface or the position of the work piece is the key factor. As a general rule, when the worker’s arm is at rest the elbow should be about 2 inches (50 mm) above the work surface. In seated workstations, this adjustment is generally accomplished by adjusting seat height. In standing workstations, which are popular in lean manufacturing concepts, height adjustment is achieved by varying work surface height.

![Diagram of ergonomic workstation design](image)

*Source: Manufacturing Engineering, Seven Key Factors for Ergonomic Workstation Design*

**Figure 1.** Areas of reach for a woman 5.5 feet tall

In any type of workplace, a minimum of 3 feet of width is required for workers to comfortably perform their tasks. In a seated workstation, the area beneath the work surface should allow sufficient foot space (1.8 feet deep and 1.15 feet high). In addition, care must be taken when drawers, shelves, or other components are installed in this area.

The work piece will influence your decision on whether to use a standing or seated configuration as well as overall workstation design. Work that is highly dependent on fine motor functions, manual electronics assembly or soldering, for example, should be done at a seated workplace equipped with armrests. This alleviates excess stress on the shoulders and neck.

For other seated workstations, all work should be positioned in front of the worker, at the correct height and with all tools, parts, and materials within easy reach of the worker. That is, the worker should be able to reach all required elements within the work area without bending or stretching. In addition, the worker should never reach above shoulder level.

Standard workstation products should be designed to accommodate 95 percent of all adult male and female worker sizes to be considered truly ergonomic. However, to fit such a wide
variety of body sizes, a workstation must be extremely flexible. This flexibility includes the
ability to adjust seat and footrest height in seated workstations and tabletop height in standing
workstations, as well as the ability to reposition tools and parts containers in all workstations.

This capability comes, literally, at a price. However, many companies have found that
decreased repetitive motion problems and absenteeism, improved quality, reduced turnover,
and overall improvement in employee morale justifies increased workstation cost.

Area of Reach
Area of reach required to perform the task is the second consideration. All components, tools,
and accessories needed to complete the work should be positioned within the employee’s
reach. Having easy access to parts and tools reduces fatigue and the chance for repetitive-
stress injuries such as carpal tunnel syndrome. The area of reach in any assembly operation
can be divided into three zones: maximum area of reach, optimum area of reach, and area of
reach with both hands. Component placement should be planned to have the most frequently
used parts in the area of reach with both hands, if both hands are needed for the assembly
task. This area is also within the employee’s direct field of vision.

Source: Manufacturing Engineering, Seven Key Factors for Ergonomic Workstation Design

Figure 2. Typical fields of vision at a manual workstation. Ideally, frequently used
components and tools are placed in the area with 35 degrees on either side

Parts and tools that are frequently collected with one hand should be placed in the area of
optimum reach. Nothing should be positioned outside the maximum area of reach. For
extremely careful workstation planning, time and motion studies may be desirable to
completely optimize a worker’s movements. Time and motion studies may also reveal
process inefficiencies that can be relieved with a properly designed workstation.

Optimizing Container Layout
Workstation designers should always strive to optimize container layout to reduce
superfluous movement and speed up the parts flow rate. Containers with the most frequently
used components should always be accessible with minimum movement. Container size should be selected to match part geometry and required quantities. In addition, containers should be sized to hold enough parts to eliminate the need for excessive refill operations that would interrupt work piece flow.

If containers are stacked, heavy components should be located in containers near or on the work surface. In any case, a seated worker should never lift more than 10 pounds because it places excessive strain on the back. In addition, it is less tiring for workers to remove relatively large and heavy components from containers closer to the work surface than from upper containers. It’s also worth repeating that all containers should be within the optimum area of reach as discussed earlier. Container layouts that allow use of both hands save time.

The Circulation Factor
Potential repetitive stress injuries are not the only reason to avoid workstations that are too high. Designers should never position a workstation above the worker’s heart height. Such a configuration will reduce blood circulation and result in a rapid drop in the employee’s performance.

Similarly, designers should try to avoid tasks that involve static holding during assembly. Once again, such tasks can reduce the supply of blood to the muscles involved, causing fatigue. This in turn will result in a drop-off of coordination, one of the main factors in poor product quality. Proper fixturing of parts on the workstation is a relatively inexpensive way to achieve substantial quality improvements.

Finally, having the worker perform a number of related tasks, rather than a single repetitive step, minimizes fatigue and reduces the chance of repetitive motion injury. This is one of the reasons why the work cell concept used in lean manufacturing is becoming so popular.

Fields of Vision
Fields of vision are the fifth factor in ergonomic workstation design. Avoiding unnecessary head and eye movements saves employees from having to repeatedly refocus their vision, an action that puts strain on the eyes.

Like areas of reach, there are several fields of vision. Frequently required materials should be arranged within the optimum field of vision, which is about 15º on either side of the centerline of the employee’s head when directly facing the workstation. In this area, objects can be easily identified by eye movement without the need for head movement.

Whenever possible, designers should not arrange materials outside the maximum field of vision, which is the area encompassed by an arc ±90º from the centerline of the employee’s head when directly facing the workstation.
Containers also should be placed at the same distance to avoid having to refocus the employee’s eyes each time there is a change in the angle of vision.

Finally, designers should provide for a natural head position. For standing workstations, this is about 15° angle toward the horizontal; when seated, the correct angle is about 25° toward the horizontal.

Lighting
Lighting is another key workstation design parameter. The correct lighting for a specific task reduces errors and improves productivity.

For general machining and assembly work, for example, we recommend nominal lighting strength of about 300 lux. (Lux is a unit of illumination that takes into account both the intensity of the light source and its distance from the illuminated surface. One lux is equal to the illumination provided by a point light source of 1 candela at a distance of 3 feet.)

Fine machine work with tolerances of <0.1 mm requires nominal strength of 500 lux. Precision assembly work, such as building of radio or television sets, winding of precision wire spools, or testing and calibration, requires nominal lighting strength of 1,000 lux. High-precision assembly of electronics components and similar items requires 1,500 lux.

Workstation lighting systems are available to suit all these applications. Distance between the work surface and the light varies from 2.5 to 6 feet depending on the specific operation. Systems also can handle indirect lighting, alternating light strengths, and other specific application requirements.

Source: Manufacturing Engineering, Seven Key Factors for Ergonomic Workstation Design

Figure 3. Based on AutoCAD, Bosch’s MASsoft package lets users quickly incorporate assemblies, 3-D models of humans, and workstation components into 2-D or 3-D drawings.
Correct adjustment of working aids such as desks, chairs, foot supports, and other peripheral equipment is the final workstation design consideration.

**Working Aids**
Correctly adjusted working aids reduce strain and downtime while increasing productivity and worker performance. Workstation components should have adjustment capability sufficient to allow employees to maintain an ergonomic and fatigue-free posture. Just as important, the adjustment itself should be easy, to ensure that the worker takes advantage of the ergonomic aspects of a chair, footrest, or adjustable tabletop.

For example, employees should be able to adjust the height and distance of components and tools to suit their needs. When chair and footrest position is correct, the thigh and the calf should form a right angle. Moveable material trolleys should be positioned within reach and angled to enhance accessibility. Box-moving equipment usage can prevent fatigue and possible injury resulting from positioning heavy components.

*Repetitive Motion Tasks*
The following is taken from the U.S. Department of Labor, OSHA, *Preventing Repetitive Stress Injuries*.

Repetitive motion tasks can result in repetitive stress injuries (RSIs). Occupational RSIs, comprise more than one hundred different types of job-induced injuries and illnesses resulting from wear and tear on the body. RSIs are one of the fastest growing workplace injuries, and can result any time there is a mismatch between the physical requirements of the job and the physical capacity of the human body. Specific risk factors that can cause RSIs include repetitive motion, force, awkward posture, heavy lifting, or a combination of these factors.

RSIs can be so severe that they inhibit the ability to accomplish many simple activities or destroy a worker’s ability to continue to perform the job.

Ergonomics, the science of adjusting the job to fit the body’s needs, can prevent RSIs. Ergonomic solutions need not be expensive; in fact, the solutions are often simple. While in some cases redesigning the workplace is the best way to prevent RSIs, often many simple and inexpensive remedies will eliminate a significant portion of the problem. For instance, taking more frequent short breaks to rest muscles; providing lifting equipment so workers won’t strain their backs lifting by themselves; or varying tasks to break up the routine of activities.

*Work/Rest Cycle*
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

If a task demands more of the worker than can be sustained, rest pauses must be taken. A general principle governing the schedule of work/rest cycles is to break up excessively heavy work into bouts of work that are as short as is practical for the task at hand. Frequent short
rest periods reduce cumulative fatigue better than a few long breaks. The worst procedure is to let the worker go home early, exhausted.

A formula has been used to estimate the percentage of time that should be allotted to rest:

$$ T_{\text{rest}}(\%) = \frac{M_{\text{max}} - M}{M_{\text{rest}} - M} \times 100 $$

In the formula, $T_{\text{rest}}$ is the percentage of rest time; $M_{\text{max}}$ is the upper limit of the metabolic cost for sustained work; $M$ is the metabolic cost of the task; and $M_{\text{rest}}$ represents the resting (sitting) metabolism.

For example, suppose that $M_{\text{max}}$ equals 350 kcal/h; and that an average value for $M_{\text{rest}}$ is 100 kilocalories per hour (kcal/h). Then assume that the task requires 524 kcal/h, which is obviously too high. Apply these values to the formula as follows:

$$ T_{\text{rest}}(\%) = \frac{350 - 525}{100 - 525} \times 100 = \frac{-175}{-425} \times 100 = 41\% $$

Thus, for this kind of work, rest pauses should be scheduled to last a total of 41 percent (24 minutes) of the hour.

**Temperature and Other Environmental Extremes**

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene.*

Heat Stress Indices

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

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

Indoors or outdoors with no solar load:

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

Outdoors with solar load:

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

where

$T_{\text{nwb}} =$ natural wet bulb temperature
\[ T_{gt} = \text{globe temperature} \]
\[ T_{db} = \text{dry bulb temperature} \]

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

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

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

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

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

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

Frostbite occurs when the skin tissues freeze. Theoretically, the freezing point of the skin is about 30 °F; however, with increasing wind velocity, heat loss is greater and frostbite occurs more rapidly. Once started, freezing progresses rapidly. For example, if the wind velocity reaches 20 mph, exposed flesh can freeze within about 1 minute at 14 °F. Furthermore, if the skin comes in direct contact with objects whose surface temperature is below the freezing point, frostbite can develop at the point of contact despite warm environmental temperatures.
Air movement is more important in cold environments than in hot because the combined effect of wind and temperature can produce a condition called windchill. The windchill index should be consulted by everyone facing exposure to low temperature and strong winds.

c. With support from a design engineer, read and interpret relevant portions of design drawings, plans, and specifications to anticipate and minimize exposure to identify potential health stressors.

Note: This is a performance-based KSA. The Qualifying Official will evaluate its completion.

3. Industrial hygiene personnel shall demonstrate a working level knowledge of study and observation methods required to recognize and evaluate potential workplace health stressors.

a. Discuss how the presence and use of existing control measures affect the evaluation of health stressors.

The following is taken from DOE G 440.1-1A.

Existing control measures are already providing a level of safety. They are used either to minimize the formation of health stressors, or to identify patterns or trends that indicate additional or increased health stressors. The existing control measures are either preventive or for use in identifying health stressors.

DOE G 440.1-1A, Worker Protection Management for DOE Federal and Contractor Employees Guide for Use with DOE Order 440.1B, states that DOE O 440.1 requires assessment of worker exposure to chemical, physical, biological, and ergonomic hazards.

Monitoring results should be recorded with documentation that describes the tasks and locations where monitoring occurred, and which identifies workers monitored or represented by the monitoring, sampling methods and durations and control measures in place during monitoring (including the use of PPE), and any other factors that may have affected sampling results.

DOE G 440.1-3, Implementation Guide for Use with DOE Order 440.1, Occupational Exposure Assessment, states that qualitative exposure information and quantitative data may also be used to determine the adequacy of existing work controls. This may be done by comparing the exposure levels under existing controls with the operational exposure limits. Once levels under existing controls have been examined, it may be necessary to modify the controls or add new controls. PPE used for controls should provide adequate protection of the worker while avoiding any unnecessary stress that may be associated with wearing PPE.

b. Describe how the following sensory indications may help with the identification of exposures:
   - Odor
   - Hearing
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Field surveys allow industrial hygienists to make use of their sensory perceptions (vision, hearing, and sense of smell) to note potential hazards. Observing dusty operations, patterns of shavings or powder on the floor, over-spray on walls, puddles underneath valves, or wetness around an area not currently in use alerts the industrial hygienist to problems not considered before. The exact location of processes of concern, such as welding stations, degreasers, flammable storage, exits and break areas can be precisely located and added to the facility layout for later consideration.

The absence or presence of visible dust should not sway initial judgment excessively. Because dust particles of respirable size are not visible to the unaided eye, lack of a visible dust cloud does not guarantee an atmosphere free of respiratory hazards. Timing of dry sweeping and shaking out of dust collection devices should be noted. The need for air sampling for dusts should be determined by the source, identity, toxicity, health complaints, and processes of concern.

Whenever a tour guide must move closer to the industrial hygienist in order to be understood, it is likely that noise levels are excessive and this fact should be noted. Patterns of hearing protector use should also be recorded during a walkthrough.

The presence of many vapors and gases is detectable by smell. The odor thresholds for some chemicals are in the parts per billion range, which helps serve as an early warning of exposure. This is especially true for someone entering an area from elsewhere and for certain aromatic or strong-smelling chemicals such as ethyl acrylate or hydrogen sulfide. The sense of smell fatigues with time and is variable from person to person. Odor thresholds listed in resource tables can vary by a factor of 100 from one person to another. Detecting an odor or experiencing eye or throat irritation should indicate to the occupational health professional that a chemical is present to some degree in the air, and an attempt should be made to identify the process or chemical. These sensory impressions do not necessarily reveal an overexposure, but they can provide important clues to a potentially hazardous source. Also, it is important to note that absence of an odor or irritation does not necessarily mean the absence of chemical exposure.

The following is taken from *Basics of Industrial Hygiene* by Debra Nims.

The response of the skin to a hazardous material is dependent on a number of variables, such as:
- The physical condition of the skin
- The environmental conditions under which the exposure occurs
- The amount of moisture present or relative dryness of the skin
- The amount of pigmentation present in the skin
- The location on the body where the material contacts the skin
• The age and gender of the worker
• Pre-existing damage or allergies
• The personal hygiene habits of the worker

The physical condition of the worker’s skin is of critical importance when considering the protective abilities of the skin. Dryness and cracking, irritation, sunburn, cuts, and other damage will lower the skin’s ability to provide an effective protective barrier. The environmental conditions under which the exposure occurs can also influence the skin’s ability to function as an effect barrier. High temperatures and humidity can create a layer of moisture on the skin, where hazardous material may dissolve. In a hot environment, enlarged pores and increased moisture from sweating enhance the permeability of the skin. This facilitates absorption of some materials. Highly pigmented skin may be able to withstand increased exposure to ultraviolet radiation without suffering permanent damage. However, even dark skin is susceptible to sunburn.

4. Industrial hygiene personnel shall demonstrate an expert level knowledge of occupational illnesses and their signs and symptoms and what their presence may indicate about past and current workplace exposure.

a. Discuss common signs and symptoms that may indicate an occupational illness or exposure.

The following is taken from NIOSH, *Asthma and Allergies*.

Signs and symptoms indicating occupational illness or exposure vary depending on the materials/chemicals to which a person is exposed. Some of the most prevalent symptoms and signs are nausea, headache, and cold-like symptoms. Symptoms for various other exposures are covered below.

*Occupational Asthma*

Agents encountered by workers can also cause allergic problems such as asthma, nasal and sinus allergies, hives, and even severe anaphylactic reactions. Asthma is one of the more serious problems that can be caused by work-related allergy. It can cause recurrent attacks of symptoms such as wheezing, chest tightness, shortness of breath, and coughing. In severe cases, these symptoms can be disabling.

*Exposure to Mercury*

The following is taken from the U.S. Department of Labor, OSHA, *Occupational Safety and Health Guideline for Mercury Vapor*.

Acute Exposure

Acute inhalation of mercury vapor may result in toxicity similar to metal fume fever including chills, nausea, general malaise, tightness in the chest, chest pains, dyspnea, cough, stomatitis, gingivitis, salivation, and diarrhea.
Chronic Exposure
Chronic exposure to mercury may result in weakness, fatigue, anorexia, weight loss, and disturbance of gastrointestinal function. A tremor may develop beginning with the fingers, eyelids, and lips which may progress to generalized trembling of the entire body and violent chronic spasms of the extremities. Parallel with development of the tremors, behavioral and personality changes may develop, including increased excitability, memory loss, insomnia, and depression. The skin may exhibit abnormal blushing, dermographia, excessive sweating and irregular macular rashes. Severe salivation and gingivitis are also characteristic of chronic toxicity. Another manifestation of chronic mercury exposure is characterized by apathy, anorexia, flush, fever, a nephrotic syndrome with albuminuria and generalized edema, diaphoresis, photophobia, insomnia and a pruritic and sometimes painful scaling or peeling of the skin of the hands and feet with bullous lesions.

Overexposure to Lead
The following is taken from the U.S. Department of Labor, OSHA, *Occupational Exposure to Lead*.

The record demonstrates that lead has profoundly adverse effects on the health of workers in the lead industry. Inhalation, the most important source of lead intake, and ingestion result in damage to the nervous, urinary, and reproductive systems and inhibit synthesis of the molecule heme, which is responsible for oxygen transport in living systems. The adverse health effects associated with exposure to lead range from acute, relatively mild, perhaps reversible stages such as inhabitation of enzyme activity, reduction in motor nerve conduction velocity, behavioral changes, and mild central nervous systems (CNS) symptoms, to permanent damage to the body, chronic disease, and death.

The signs and symptoms of severe lead intoxication which occur at blood lead levels of 80 μg/100 g and above are well documented. The symptoms of severe lead intoxication are known from studies carried out many years ago and include loss of appetite, metallic taste in the mouth, constipation, nausea, pallor, excessive tiredness, weakness, insomnia, headache, nervous irritability, muscle and joint pains, fine tremors, numbness, dizziness, hyperactivity, and colic. In lead colic, there may be severe abdominal pain, such that abdominal surgery mistakenly has occasionally been performed.

Damage to the CNS in general and the brain (encephalopathy) in particular is the most severe clinical form of lead intoxication. The most severe, often fatal, form of encephalopathy may be preceded by vomiting, apathy progressing to drowsiness and stupor, poor memory, restlessness, irritability, tremor, and convulsions. It may arise precipitously with the onset of intractable seizures, followed by coma, cardiorespiratory arrest, and death. There is a tendency toward the occurrence of weakness of extensor muscle groups, which is motor impairment. This weakness may progress to palsy, often observed as a characteristic wrist drop or foot drop and is a manifestation of a disease to the peripheral nervous system (peripheral neuropathy). Lead intoxication also results in kidney damage with few, if any, symptoms appearing until extensive and most likely permanent kidney damage has occurred.
Of considerable concern are the effects resulting from long-term lead exposure. There is evidence that prolonged exposure can increase the risk of nephritis, mental deficiency, premature aging, and high blood pressure.

Exposure to lead results in decreased libido, impotence and sterility in men and decreased fertility, abnormal menstrual and ovarian cycles in women. The course of pregnancy is adversely affected by exposure to lead. There is conclusive evidence of miscarriage and stillbirth in women who were exposed to lead or whose husbands were exposed. Children born of parents either of whom were exposed to lead are more likely to have birth defects, mental retardation, behavioral disorders, or die during the first year of childhood.

b. Discuss basic concepts of toxicology, including dose-response relationship, routes of exposure, and other topics (e.g., synergism, potentiation, and hyper-susceptibility).

The following is taken from the Extension Toxicology Network, Dose-Response Relationships in Toxicology.

The science of toxicology is based on the principle that there is a relationship between a toxic reaction (the response) and the amount of poison received (the dose). An important assumption in this relationship is that there is almost always a dose below which no response occurs or can be measured. A second assumption is that once a maximum response is reached, any further increases in the dose will not result in any increased effect.

One particular instance in which this dose-response relationship does not hold true is in regard to true allergic reactions. Allergic reactions are special kinds of changes in the immune system; they are not really toxic responses. The difference between allergies and toxic reactions is that a toxic effect is directly the result of the toxic chemical acting on cells. Allergic responses are the result of a chemical stimulating the body to release natural chemicals which are in turn directly responsible for the effects seen. Thus, in an allergic reaction, the chemical acts merely as a trigger, not as the bullet.

For all other types of toxicity, knowing the dose-response relationship is a necessary part of understanding the cause and effect relationship between chemical exposure and illness. The toxicity of a chemical is an inherent quality of the chemical and cannot be changed without changing the chemical to another form. The toxic effects on an organism are related to the amount of exposure.

Routes of Exposure
The following is taken from National Safety Council, Fundamentals of Industrial Hygiene.

To exert its toxic effect, a harmful agent must come into contact with a body cell and must enter the body via inhalation, skin absorption, or ingestion.
Inhalation
Inhalation involves airborne contaminations that can be inhaled directly into the lungs and can be physically classified as gases, vapors, and particulate matter, including dusts, fumes, smokes, aerosols, and mists.

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

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

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

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

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

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

It is important to study all routes of entry when evaluating the work environment—candy bars or lunches in the work area, solvents being used to clean work clothing and hands, in addition to airborne contaminants in working areas.

Synergism
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Synergism is known to occur with certain exposures. The best-known synergistic effect is that of smoking combined with asbestos exposure. The risk of lung cancer increase greatly beyond that expected from adding the risks together. Similarly, in vitro studies of organic phosphorus pesticides have shown that a combined exposure to malathion and diazinon...
results in cholinesterase inhibition significantly greater than a mere summation of the effect would predict.

Other research has focused on less obvious combined effects. One study looked at the effect of different chemicals on hearing and found that trichloroethylene, arsenic, heavy metals, organo-tin compounds, and manganese all caused some degree of hearing loss or audiometric abnormalities in occupationally exposed workers. Carbon disulfide interacted with noise to cause sensorineural hearing loss; toluene and noises acted synergistically to increase the incidence of hearing loss. Another study, looking at the combined effects of chemicals commonly found at hazardous waste sites, saw both synergistic and antagonistic interactions.

The OSHA airborne exposure limits have been developed under the assumption that workers are exposed to chemicals one at a time. In fact, exposure to just a single chemical rarely occurs. One method to calculate the alteration in guidelines necessary to evaluate combined exposure is to add concentrations as a fraction of their respective TLVs. If the total equals to or exceeds one, then an overexposure has been detected. This is not a conservative approach, because it assumes additive effects and allows excessive exposures if the effects are synergistic or if the stressors are present.

In most workplace exposure assessments, chemical, physical, biological, and psychological hazards are present at the same time. For example, the process of tunneling can involve simultaneous exposures to high atmospheric pressure, dust, noise, heat, high humidity, carbon monoxide, and physical safety hazards. An assessment of strain produced by any one of these stressors would be complicated by the presence of any or all of the others.

Potentiation
According to the Agency for Toxic Substances and Disease Registry (ATSDR), Interaction Profiles for Toxic Substances, potentiation occurs when a component that does not have a toxic effect on an organ system increases the effect of a second chemical on that organ system.

Hyper-susceptibility
According to National Safety Council, Fundamentals of Industrial Hygiene, hyper-susceptibility refers to the occurrence of the usual health effects caused by a substance following exposures to air levels below that associated with effects for most individuals. The substance affects its usual target but at lower doses. If exposure ends, there is no immunologic memory, in contrast to an allergy.

c. Discuss examples of workplace stressors and appropriate toxicological reference material for disorders of the central nervous system, respiratory system, as well as skin, ear, liver, kidney, and other target organ effects. For example, discuss some of the following:

- Asbestosis
- Mesothelioma
- Pneumoconiosis
- Dermatitis
- Cumulative trauma disorder
- Chronic beryllium disease
- Dermatosis
- Hypersensitivity pneumonitis
- Chronic obstructive lung disease
- Occupational asthma
- Bronchogenic carcinoma
- Glomerulonephritis
- Cirrhosis of liver
- Jaundice

Asbestosis
Title 29 CFR 1910.1001 defines asbestosis as a disabling fibrotic lung disease caused only by exposure to asbestos. Exposure to asbestos has also been associated with an increased incidence of esophageal, kidney, laryngeal, pharyngeal, and buccal cavity cancers. As with other known chronic occupational diseases, disease associated with asbestos generally appears about 20 years following the first occurrence of exposure: There are no known acute effects associated with exposure to asbestos.

Asbestosis is pulmonary fibrosis caused by the accumulation of asbestos fibers in the lungs. Symptoms include shortness of breath, coughing, fatigue, and vague feelings of sickness. When the fibrosis worsens, shortness of breath occurs even at rest. The diagnosis of asbestosis is based on a history of exposure to asbestos, the presence of characteristic radiologic changes, end-inspiratory crackles (rales), and other clinical features of fibrosing lung disease. Pleural plaques and thickening are observed on x-rays taken during the early stages of the disease. Asbestosis is often a progressive disease even in the absence of continued exposure, although this appears to be a highly individualized characteristic. In severe cases, death may be caused by respiratory or cardiac failure.

Mesothelioma
The following is taken from the U.S. National Institutes of Health, National Cancer Institute, *Mesothelioma: Questions and Answers*.

Mesothelioma (cancer of the mesothelium) is a disease in which cells of the mesothelium become abnormal and divide without control or order. They can invade and damage nearby tissues and organs. Cancer cells can also metastasize (spread) from their original site to other parts of the body. Most cases of mesothelioma begin in the pleura or peritoneum.

Working with asbestos is the major risk factor for mesothelioma. A history of asbestos exposure at work is reported in about 70 percent to 80 percent of all cases. However, mesothelioma has been reported in some individuals without any known exposure to asbestos.

Asbestos is the name of a group of minerals that occur naturally as masses of strong, flexible fibers that can be separated into thin threads and woven. Asbestos has been widely used in many industrial products, including cement, brake linings, roof shingles, flooring products, textiles, and insulation. If tiny asbestos particles float in the air, especially during the manufacturing process, they may be inhaled or swallowed, and can cause serious health problems. In addition to mesothelioma, exposure to asbestos increases the risk of lung
cancer, asbestosis (a noncancerous, chronic lung ailment), and other cancers, such as those of the larynx and kidney.

Smoking does not appear to increase the risk of mesothelioma. However, the combination of smoking and asbestos exposure significantly increases a person’s risk of developing cancer of the air passageways in the lung.

Symptoms of mesothelioma may not appear until 30 to 50 years after exposure to asbestos. Shortness of breath and pain in the chest due to an accumulation of fluid in the pleura are often symptoms of pleural mesothelioma. Symptoms of peritoneal mesothelioma include weight loss and abdominal pain and swelling due to a buildup of fluid in the abdomen. Other symptoms of peritoneal mesothelioma may include bowel obstruction, blood clotting abnormalities, anemia, and fever. If the cancer has spread beyond the mesothelium to other parts of the body, symptoms may include pain, trouble swallowing, or swelling of the neck or face.

These symptoms may be caused by mesothelioma or by other, less serious conditions. It is important to see a doctor about any of these symptoms. Only a doctor can make a diagnosis.

Pneumoconiosis

The following is taken from Everyday Health, Pneumoconiosis.

Pneumoconiosis is a lung condition that is caused by inhaling particles of mineral dust, usually while working in a high-risk, mineral-related industry. At first, irritating mineral dust can trigger lung inflammation, which causes areas of the lung to be temporarily damaged. Over time, these areas can progress to form tough, fibrous tissue deposits. This stage of pneumoconiosis is called fibrosis. Fibrosis stiffens the lungs and interferes with the lung's normal exchange of oxygen and carbon dioxide.

There are several different types of pneumoconiosis. In the United States, the most common types include:

Asbestosis

Asbestos is the general name for a family of irritating fibrous minerals that are mined from underground deposits and used in the manufacture of home insulation, fireproof materials, tiles for floors and ceilings, automobile brake linings, and other products. Workers with the highest asbestos exposure include miners, construction workers, demolition workers, shipbuilders and auto mechanics who work with brakes. Asbestos exposure also can affect people who live or work in buildings where asbestos-containing building products are deteriorating. In most cases, signs of asbestosis do not develop for 20 or more years after a person is first exposed to asbestos dust.

Silicosis

This form of pneumoconiosis affects people who work with silica, usually in the form of quartz that is found in sand, sandstone, slate, some clays, granite and other ores. Workers with the highest exposure to silica include sandblasters, miners, tunnel builders, silica
millers, quarry workers, foundry workers and those who make ceramics or glass. Silicosis can cause progressive fibrosis in the lung with a significant decrease in lung function, especially in cigarette smokers.

Coal Worker’s Pneumoconiosis
This form of pneumoconiosis is caused by inhaling carbon particles from coal, graphite, lamp black or carbon black. It most often affects people who mine, process or ship coal; graphite miners; and workers who manufacture synthetic graphite, lamp black or carbon black. Like silicosis, coal worker's pneumoconiosis can cause significant fibrosis, primarily in miners who have worked for decades without protective equipment.

Talc Pneumoconiosis
This is caused by exposure to talc dust, usually during talc mining or milling. Talc pneumoconiosis also can lead to lung fibrosis.

Kaolin (China Clay) Pneumoconiosis
This pneumoconiosis is caused by inhaling kaolin, an ingredient used in the manufacture of ceramics, paper, medicines, cosmetics and toothpaste. Workers who mine, mill or bag kaolin are at risk.

Siderosis of the Lung
This pneumoconiosis, also known as welder’s lung or silver polisher’s lung, is caused by inhaling iron particles. Although welder’s lung often looks abnormal on a chest X-ray, it usually does not cause any symptoms.

Other Pneumoconiosis
Less often, pneumoconiosis can be caused by inhaling barium sulfate, tin oxide, compounds containing hard metal (cobalt and tungsten carbide) or other forms of mineral dust.

Dermatitis
The following is taken from the U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, Medical Encyclopedia, Rashes.

Dermatitis is an area of irritated or swollen skin. It might be red and itchy, bumpy, scaly, crusty or blistered. Dermatitis is a symptom of many different medical conditions. Things that can cause dermatitis include other diseases, irritating substances, allergies, and genetic makeup.

Contact dermatitis is a common cause of rashes. It causes redness, itching and burning where a person has touched an irritant, such as a chemical, or something the person is allergic to, like poison ivy.

Some rashes develop immediately. Others form over several days. If the rash is scratched, it might take longer to heal. The treatment for dermatitis usually depends on its cause. Options
Cumulative Trauma Disorder
The following is taken from About.com, Ergonomics: What is Cumulative Trauma Disorder?.

A cumulative trauma disorder is a condition where a part of the body is injured by repeatedly overusing or causing trauma to that body part.

Trauma occurs when the body part is called on to work harder, stretch farther, impact more directly or otherwise function at a greater level than it is prepared for. The immediate impact may be minute, but when it occurs repeatedly the constant trauma cause damage.

The term cumulative trauma disorder identifies a large group of conditions that result from traumatizing the body in either a minute or major way over a period of time. It is the build up of trauma that causes the disorder.

These conditions are often focused on a joint and usually affect the muscle, bone, tendon or bursa of the joint. However other anatomical features and areas can be stressed and their response to that trauma can be an injury.

Some common examples of cumulative trauma disorders are:
- Carpal Tunnel Syndrome
- Tendonitis
- Bursitis
- Tennis Elbow
- Trigger Finger
- Blackberry Thumb
- Vibration White Finger
- Shin Splints
- Calluses
- Bunyan

Chronic Beryllium Disease
The following is taken from 10 CFR 850.

DOE has a long history of beryllium use because of the element’s broad application to many nuclear operations and processes. Beryllium metal and ceramics are used in nuclear weapons, as nuclear reactor moderators or reflectors, and as nuclear reactor fuel element cladding. At DOE, beryllium operations have historically included melting, casting, grinding, and machine tooling of parts.

Inhalation of beryllium dust or particles can cause chronic beryllium disease (CBD) or beryllium sensitization. CBD is a chronic, often debilitating, and sometimes fatal lung condition. Beryllium sensitization is a condition in which a person’s immune system
becomes highly responsive (allergic) to the presence of beryllium in the body. There has long been scientific consensus that exposure to airborne beryllium is the only cause of CBD.

Chronic beryllium disease is a granulomatous lung disease that is caused by the body’s immune system response (similar to an allergic reaction) to inhaled dust or fumes containing beryllium metal, alloys, beryllium compounds or mixtures, or insoluble beryllium salts. The body’s immune system response to beryllium is often called beryllium sensitization.

Beryllium sensitization precedes the development of CBD. Sensitization can occur quickly or many years after exposure to beryllium, progressing into disease at a rate of approximately 10 percent a year.

It is hypothesized that beryllium is a hapten (a substance that provokes an immune response only when combined with another substance, generally a protein) that binds to peptides on mucosal surfaces. In susceptible individuals the beryllium-peptide complex initiates an immune response, which may progress ultimately to granuloma formation in the pulmonary interstitium. Data have suggested that CBD can occur at relatively low exposure levels and in some cases, after relatively brief durations of exposure.

The International Agency for Research on Cancer and ACGIH classify beryllium as a human carcinogen. Frequently reported symptoms include one or more of the following: dyspnea (shortness of breath) on exertion, cough, fever, night sweats, and chest pain and, less frequently, arthralgias (neuralgic pain in joints), fatigue, weight loss, or appetite loss. On physical examination, a doctor may find signs of CBD results, such as rales (changes in lung sounds), cyanosis (lack of oxygen), digital clubbing, or lymphadenopathy (enlarged lymph nodes). A radiograph (x-ray) of the lungs may show many small scars. Patients may also have an abnormal breathing test, pulmonary function test, a blood test, and the peripheral blood beryllium-induced lymphocyte proliferation test. Examination of the lung tissue under the microscope may show granulomas, which are signs of damage due to the body’s reaction to beryllium. CBD may be confused with other lung diseases, especially sarcoidosis. In advanced cases, there may be manifestations of right-sided heart failure, including cor pulmonale (enlarged right ventricle of the heart caused by blockage in the lungs).

Dermatosis
Per U.S. National Institutes of Health, National Cancer Institute, Definitions of Cancer Terms, dermatosis is a skin disease marked by scaly or thickened patches on the skin, and often caused by prolonged exposure to arsenic. The patches often occur on sun-exposed areas of the skin and in older white men. These patches may become malignant (cancerous). It is also called Bowen disease or precancerous dermatitis.

Hypersensitivity Pneumonitis
The following is taken from U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, Medical Encyclopedia, Hypersensitivity Pneumonitis.

Hypersensitivity pneumonitis is inflammation of the lungs due to breathing in a foreign substance, usually certain types of dust, fungus, or molds.
Hypersensitivity pneumonitis usually occurs in those who work in places where there are high levels of organic dusts, fungus, or molds. For example, farmer’s lung is the most common type of hypersensitivity pneumonitis. Repeated or intense exposure to dust from moldy hay, straw, and grain can lead to lung inflammation and acute lung disease. Over time, this acute condition may turn into long-lasting (chronic) lung disease.

The condition may also result from fungus present in humidifiers, heating systems, and air conditioners found in homes and offices. Exposure to certain bird droppings (for example, among bird owners) can also lead to hypersensitivity pneumonitis.

Symptoms of acute hypersensitivity pneumonitis may occur 4–6 hours after leaving the area where the foreign substance is found. These symptoms may include cough, fever, chills, shortness of breath, or malaise (feeling ill). Symptoms of chronic hypersensitivity pneumonitis may include breathlessness, especially with exertion; cough, often dry; loss of appetite; and unintentional weight loss.

*Chronic Obstructive Lung Disease*

The following is taken from the U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, Medical Encyclopedia, *Chronic Obstructive Pulmonary Disease*.

Chronic obstructive pulmonary disease (COPD) is a group of lung diseases that cause swelling of the airways. Emphysema and chronic bronchitis are the most common forms of COPD.

The leading cause of COPD is smoking. Between 15 percent and 20 percent of long-term smokers will develop COPD. Prolonged tobacco use causes lung inflammation and destroys air sacs in the lungs. (In rare cases, an enzyme deficiency called alpha-1 anti-trypsin deficiency can cause emphysema in non-smokers.)

Other risk factors for COPD are exposure to secondhand smoke, male gender, and working or living in a polluted environment.

Symptoms include shortness of breath (dyspnea) persisting for months to years, wheezing, decreased exercise tolerance, and cough with or without phlegm.

*Occupational Asthma*

The following is taken from the U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, Medical Encyclopedia, *Occupational Asthma*.

Occupational asthma is a lung disorder in which various substances found in the workplace lead to breathing difficulties.

Many substances in the workplace can cause occupational asthma. The most common triggers are wood dust, grain dust, animal dander, fungi, or other chemicals (especially diisocyanates). Though the actual rate of occurrence of occupational asthma is unknown, it is suspected to cause 2–20 percent of all cases of asthma in industrialized nations.
Symptoms are usually due to airway inflammation and spasms of the muscles lining the airways, which cause the muscles to narrow excessively. They usually occur shortly after being exposed to the offending substance and often improve or disappear when a person leaves work. Some people may not have symptoms until 12 or more hours after exposure to the allergen. Symptoms usually get worse toward the end of the work week and may (but not always) go away on weekends or vacations. In general, symptoms include coughing, tight feeling in the chest, shortness of breath, and wheezing.

**Bronchogenic Carcinoma**

The following is taken from the U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, Medical Encyclopedia, *Lung Cancer*.

Bronchogenic carcinoma is one of the most common cancers in the world. It is a leading cause of cancer death in men and women in the United States. Cigarette smoking causes most lung cancers. The more cigarettes you smoke per day and the earlier you started smoking, the greater your risk of lung cancer. High levels of pollution, radiation, and asbestos exposure may also increase risk.

Common symptoms of lung cancer include the following:
- A cough that doesn’t go away and gets worse over time
- Constant chest pain
- Coughing up blood
- Shortness of breath, wheezing, or hoarseness
- Repeated problems with pneumonia or bronchitis
- Swelling of the neck and face
- Loss of appetite or weight loss
- Fatigue

There are many types of lung cancer. Each type of lung cancer grows and spreads in different ways and is treated differently. Treatment also depends on the stage, or how advanced it is. Treatment may include chemotherapy, radiation, and surgery.

**Glomerulonephritis**

The following is taken from U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, Medical Encyclopedia, *Rapidly Progressive Glomerulonephritis*.

Rapidly progressive glomerulonephritis is a form of kidney disease that causes damage to the small structures (glomeruli) inside the kidneys that help filter waste and fluids from blood to form urine. The disease leads to a rapid loss of kidney function.

Many conditions are known to cause or increase the risk for developing rapidly progressive glomerulonephritis. These include the following:
- Abscess of any internal organ
- Anti-glomerular basement membrane antibody disease
- Blood vessel diseases such as vasculitis or polyarteritis
- Collagen vascular disease such as lupus nephritis and Henoch-Schonlein purpura
- Goodpasture syndrome
- IgA nephropathy
- Membranoproliferative glomerulonephritis

The following increase your risk of developing this condition:
- History of cancer
- Blood or lymphatic system disorders
- Exposure to hydrocarbon solvents

Rapidly progressive glomerulonephritis includes any type of glomerulonephritis (inflammation of the glomerulus) in which progressive loss of kidney function occurs over weeks to months.

The disorder is more common in certain geographic areas. Mini-epidemics of this disorder have also occurred. Rapidly progressive glomerulonephritis is most common in people age 40–60, and slightly more common in men. It is unusual in preschool children, and slightly more common in later childhood.

Common symptoms include the following:
- Edema (swelling) of the face, eyes, ankles, feet, legs, or abdomen
- Blood in the urine
- Dark or smoke-colored urine
- Decreased urine volume

Symptoms that may also appear include the following:
- Abdominal pain
- Cough
- Diarrhea
- General ill feeling
- Fever
- Joint aches
- Muscle aches
- Loss of appetite
- Shortness of breath

_Cirrhosis of Liver_

The following is taken from the U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, _Cirrhosis_.

Cirrhosis is scarring of the liver. Scar tissue forms because of injury or long-term disease. Scar tissue cannot do what healthy liver tissue does—make protein, help fight infections, clean the blood, help digest food and store energy. Cirrhosis can lead to
- easy bruising or bleeding, or nosebleeds
- swelling of the abdomen or legs
- extra sensitivity to medicines
- high blood pressure in the vein entering the liver
- enlarged veins in the esophagus and stomach
kidney failure

About 5 percent of people with cirrhosis get liver cancer.

Cirrhosis has many causes. In the United States, the most common causes are chronic alcoholism and hepatitis. Nothing will make the scar tissue disappear, but treating the cause can keep it from getting worse. If too much scar tissue forms, a liver transplant may be required.

Jaundice

The following is taken from the U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus, Jaundice.

Jaundice causes the skin and the whites of eyes to turn yellow. Too much bilirubin causes jaundice. Bilirubin is a yellow chemical in hemoglobin, the substance that carries oxygen in red blood cells. As red blood cells break down, the body builds new cells to replace them. The old ones are processed by the liver. If the liver cannot handle the blood cells as they break down, bilirubin builds up in the body and the skin may look yellow.

Many healthy babies have some jaundice during the first week of life. It usually goes away. However, jaundice can happen at any age and may be a sign of a problem. Jaundice can happen for many reasons, such as the following:

- Blood diseases
- Genetic syndromes
- Liver diseases, such as hepatitis or cirrhosis
- Blockage of bile ducts
- Infections
- Medicines

d. Discuss the following basic epidemiological terms and provide examples of how each is used:

- Retrospective
- Case control
- Cohort

The following definitions are taken from Statistical Help from StatsDirect, Prospective vs. Retrospective Studies.

Retrospective

A retrospective study looks backwards and examines exposures to suspected risk or protection factors in relation to an outcome that is established at the start of the study. Many valuable case-control studies, such as Lane and Claypon’s 1926 investigation of risk factors for breast cancer, were retrospective investigations. Most sources of error due to confounding and bias are more common in retrospective studies than in prospective studies. For this reason, retrospective investigations are often criticized. If the outcome of interest is uncommon, however, the size of prospective investigation required to estimate relative risk is often too large to be feasible. In retrospective studies the odds ratio provides an estimate of
relative risk. Prospective investigation is required to make precise estimates of either the incidence of an outcome or the relative risk of an outcome based on exposure.

Case-Control Studies
Case-Control studies are usually but not exclusively retrospective, the opposite is true for cohort studies. The following notes relate case-control to cohort studies:

- outcome is measured before exposure
- controls are selected on the basis of not having the outcome
- good for rare outcomes
- relatively inexpensive
- smaller numbers required
- quicker to complete
- prone to selection bias
- prone to recall/retrospective bias

related methods are risk (retrospective), chi-square 2 by 2 test, Fisher’s exact test, exact confidence interval for odds ratio, odds ratio meta-analysis and conditional logistic regression.

Cohort Studies
Cohort studies are usually but not exclusively prospective, the opposite is true for case-control studies. The following notes relate cohort to case-control studies:

- outcome is measured after exposure
- yields true incidence rates and relative risks
- may uncover unanticipated associations with outcome
- best for common outcomes
- expensive
- requires large numbers
- takes a long time to complete
- prone to attrition bias (compensate by using person-time methods)
- prone to the bias of change in methods over time

related methods are risk (prospective), relative risk meta-analysis, risk difference meta-analysis and proportions.

e. Discuss how a health and safety complaint should be investigated.

The following is taken from the U.S. Department of Labor, OSHA, How to File a Complaint with OSHA.

There are two ways that OSHA can respond to a complaint. OSHA can either perform an onsite inspection or an offsite investigation, also known as a phone/fax investigation.

Although every worker has a right to receive an onsite inspection if certain conditions are met, there are times when a phone/fax (or letter) investigation may be a better alternative. OSHA responds more quickly to lower priority hazards using a phone/fax approach. This enables the agency to concentrate resources on the most serious workplace hazards.
Employees who request a phone/fax investigation do not give up the right to request an onsite inspection of potential violations and hazards if they are not satisfied with the investigation. Workers should call their nearest OSHA area office to discuss their options.

If an offsite investigation is appropriate, the agency telephones the employer, describes the alleged hazards, and then follows up with a fax or letter. The employer must respond in writing within 5 days, identifying any problems found and noting corrective actions taken or planned. If the response is adequate, OSHA generally will not conduct an inspection. The employee or employee representative who filed the original complaint will receive a copy of the employer’s response and, if still not satisfied, may then request an onsite inspection.

If the employee or employee representative files a written complaint that meets certain conditions described in OSHA Directive CPL 2.115, or a state plan’s equivalent procedures, then OSHA may conduct an on-site inspection. Those conditions include claims of serious physical harm that have already resulted in disabling injuries or illnesses, or claims of imminent danger situations; written, signed complaints requesting inspections; and situations where the employer provided an inadequate response to a phone/fax investigation.

5. **Industrial hygiene personnel shall demonstrate the ability to recognize potential ergonomic and office health hazards.**

   a. **Use accepted protocol to identify jobs with potential ergonomic problems.**

      The following is taken from U.S. Department of Labor, OSHA, *Ergonomics, Contributing Conditions*.

      Both work-related and non-work-related conditions can either individually or by interacting with each other give rise to musculoskeletal disorders (MSDs). There are several approaches that may be used to determine whether conditions in the workplace might be contributing to employees developing MSDs. These approaches can be used individually or in combination.

      Review and analyze injury and illness records to determine whether there is a pattern of ergonomic-related injuries in certain jobs or work tasks.

      - OSHA 300 Logs and supporting 301 forms (see the Recordkeeping Home Page for more information)
      - Workers’ compensation claims

      Analyze the jobs or work tasks themselves to identify potential ergonomic problems before employee injuries occur. Determine if jobs present ergonomic risks that may contribute to musculoskeletal disorders.

      Analysis tools may help in analyzing jobs. While there is no one-size-fits-all approach, there are numerous non-OSHA, voluntary analysis tools that may be used to learn more about potential ergonomic risks associated with jobs.

      Seek employee input about the existence of ergonomic problems related to particular jobs or work tasks. This may be accomplished, among other ways:
Be aware of common contributing conditions within your industry or job classifications. If other companies in the same industry have ergonomic-related problems, then it is possible these potential problems are also your concern. Obtain information from others in your industry
- to see what problems others have experienced in their operations;
- to gain a better understanding of potential problems that may exist in your workplace.

b. Recognize and evaluate the following potential ergonomic factors:
- Equipment/tool design and selection
- Work layout
- Visual displays
- Work/rest cycles
- Work area illumination and color
- Human capacity/job demands
- Requirements for manual handling
- Alternative work schedules and shift work

Equipment/Tool Design and Selection
Over time, exposure to awkward postures or harmful contact pressures can contribute to an injury. The risk of injury can be reduced if hand tools are selected that fit comfortably and are appropriate for the job that is being performed.

Tips for Selecting Hand Tools
The following information and figures are taken from the Department of Health and Human Services, Centers for Disease Control and Prevention, Easy Ergonomic: A Guide to Selecting Non-powered Tools.

Tools used for power require high force. Tools used for precision or accuracy require low force.

For single-handle tools used for power tasks: Select a tool that feels comfortable with a handle diameter in the range of 1 ¼ inches to 2 inches. You can increase the diameter by adding a sleeve to the handle. (Examples are shown in figure 4.)

![Figure 4. Single-handle tools with sleeve](image_url)
For single-handle tools used for precision tasks: Select a tool with a handle diameter of ¼ inch to ½ inch. (See figure 5.)

Figure 5. Single-handle tools for precision tasks.

For double-handle tools (plier-like) used for power tasks: Select a tool with a grip span that is at least 2 inches when fully closed and no more than 3 ½ inches when fully open. When continuous force is required, consider using a clamp, a grip, or locking pliers. (See figure 6.)

Figure 6. Open and closed grip span

For double-handle tools (plier-like) used for precision tasks: Select a tool with a grip span that is not less than 1 inch when fully closed and no more than 3 inches when fully open. (See figure 7.)

Figure 7. Double-handle tools for precision tasks

For double-handled pinching, gripping, or cutting tool: Select a tool with handles that are springloaded to return the handles to the open position. (See figure 8.)
Select a tool without sharp edges or finger grooves on the handle. (See figure 9.)

Select a tool that is coated with soft material. Adding a sleeve to the tool handle pads the surface but also increases the diameter or the grip span of the handle. (See figure 10.)

Select a tool with an angle that allows you to work with a straight wrist. Tools with bent handles are better than those with straight handles when the force is applied horizontally (in the same direction as your straight forearm and wrist). (See figure 11.)
Tools with straight handles are better than those with bent handles when the force is applied vertically. (See figure 12.)

Select a tool that can be used with your dominant hand or with either hand. (See figure 13.)

For tasks requiring high force, select a tool with a handle length longer than the widest part of your hand—usually 4 inches to 6 inches. (See figure 14.)
Prevent contact pressure by making sure the end of the handle does not press on the nerves and blood vessels in the palm of your hand. (See figure 15.)

Figure 15. If the handle is too short, the end will press against the palm of your hand and may cause an injury.

Select a tool that has a non-slip surface for a better grip. Adding a sleeve to the tool improves the surface texture of the handle. To prevent tool slippage within the sleeve, make sure that the sleeve fits snugly during use. (See figure 16.)

Figure 16. Tools with a non-slip surface

Work Layout

The following is taken from the National Safety Council, Fundamentals of Industrial Hygiene.

The goal in designing a workstation is to promote ease and efficiency for the working person. Productivity will suffer in quantity and quality if the operator is uncomfortable, or if the layout of the workstation or the job procedures are awkward. Conversely, productivity will be enhanced if the operator is comfortable physiologically and psychologically and if the layout of the workstation is conducive to performing the task well.

The following are general rules that govern the design of workplaces:

- Plan the ideal, then the practical.
- Plan the whole, then the detail.
- Plan the work process and the equipment to fit the human.
- Plan the workplace layout around the process and the equipment.
- Use mockups to evaluate alternative solutions and to check the final design.
In this design process, the following aspects are of primary importance:

- **Space**: clearance for the operator’s body entrance and egress; suitable body movements and postures at work; operation of controls and equipment;
- **Manipulation**: operation of tools, controls, and work pieces by hand (or foot), including seat adjustment; avoidance of excessive forces or inadvertent operation of controls, use of emergency items (stop button, flashlight, survival equipment);
- **Seeing**: visual field and information both inside and outside; visual contact with co-workers; lighting;
- **Hearing**: auditory information, such as oral communication with other workers, signals and sounds from equipment.

**Visual Displays**
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

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

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

An operator must decide on the proper course of action and manipulate controls to produce any desired change in the machine’s performance. The efficiency and effectiveness—that is, the safety with which controls can be operated—depend on the extent to which information on the dynamics of human movement has been incorporated in their design. This is particularly true whenever controls must be opened at high speed, against large resistance, with great precision, or over long periods of time.

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

**Work/Rest Cycles**
See competency statement 2.b for an explanation of work/rest cycles.

**Work Area Illumination and Color**
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Insufficient light causes accidents and reduces work performance. One needs adequate lighting to see hazards in the workplace and to read information such as text and dials. Most lighting concerns are quantitative, but some qualitative concerns may also arise such as glare, contrast and color.

**Glare**

Glare, either reflected or direct, is still a major concern. Reflected glare is usually a specular reflection of a sunlit window or lamp off of a screen or other shiny surface that partially obscures or veils the scene at the reflection. Direct glare is a relatively bright object, such as an unshaded window, in an otherwise dark area that prevents the eyes from adapting to the dark area. Reflected glare can be controlled by locating the screen or other surface of interest so it does not reflect the images of windows or lamps.

A screen can be angled so it does not reflect the images of lamps or windows into the user’s eyes. In some cases, visors or partitions can be used to block light from lamps or windows. Another option is to place a textured surface above the object that breaks up specular reflections while allowing the light from the object below it to pass through.

**Contrast**

A graduation of contrasts is sought between the task and its immediate and more remote visual surroundings. In essence, strong lighting can exist in an area of moderate lighting, which can be surrounded by a dimly lit or unlit expanse, but darkness should not immediately surround brightness. An example of harsh contrast is a lit desk in a poorly lit warehouse. The lamp at the desk should be supplemented by area lighting to avoid contrast problems. People look away from their visual tasks from time to time, so the person at this desk would probably not wish to stay there because the visual contrast between the desk and its visual surroundings is too great for comfort.

**Color**

Color can be a problem if unusual fluorescent tubes or colored incandescent bulbs are installed. White light contains radiation associated with every color we can see; colored lights radiate selected wavelengths more intensely.

Colored lighting is useful for some jobs, such as blue-enhanced fluorescent tubes for greenhouse lighting or yellow-orange low-pressure sodium lamps for abundant yet cheap safety lighting at night. Colored lighting without some benefit can create difficulties. Colors may be harder to perceive when nonwhite light is used. Yellow and white objects could, for example, both appear the same in yellow or red lighting, so yellow signs and warning devices could become unreliable and blue surfaces would appear to be black.
**Human Capacity/Job Demands**

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

People perform widely differing tasks in daily work situations. These tasks must be matched with human capabilities to avoid under loading, 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. Engineering psychologists, work physiologists, and occupational biomechanists evaluate the capacities and limitations of the worker to perform work; they also determine human tolerance to stresses produced by the environment.

In the traditional system concept of engineering psychology, the human is considered a receptor and processor of information of energy, who then outputs information or energy. Input, processing, and output follow each other in sequence. The output can be used to run a machine, which may be a simple hand tool or a space craft.

The actual performance of this human technology system is monitored and compared with the desired performance. Hence, feedback loops connect the output side with the input side. The difference between output and input is registered in a comparator, and corrective actions are taken to minimize any output/input difference. In this system the human controls, compares, makes decision, and corrects.

Affordance is the property of an environment that has certain values to the human. 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 or human engineering provides affordances.

Traditional engineering psychologists describe our activities as a linear sequence of stages, from perception to decision to response. Research is done separately on each of these stages, on their substages, and on other connections. Such independent, stage-related information is then combined into a linear model.

**Requirements for Manual Handling**

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

There are seven keys used as ergonomic tools for safe and efficient material handling:

1. **Facility Layout**—Initial layout or improvement of facilities contributes essentially towards safe and efficient material transfer. The selection of either product or process layout and accordingly how the flow of material is organized and designed in detail, determines how people are involved and how they must handle material.

2. **Job Design**—Job design determines the stress imposed on the worker by the work. Initially, the engineer must decide whether to assign certain tasks to a person or to a machine. Furthermore, the layout of the task, the kind of material-handling motions to be performed, the organization of work and rest periods, an many other engineering
and managerial techniques determine whether a job is well-designed, safe, effective and agreeable for the operator.

3. Equipment—Selection, use, and improvement of equipment, machines, and tools strongly affect handling requirements. Ergonomic principles must be considered, for example, operator space requirements, control design, visibility, and color and sign coding.

4. People—This key concerns people as material handlers, particularly with regard to body size, strength, and energy capabilities. People are the kingpins in manual material activities because they supervise, control, operate, drive, and actually handle material. If people are not needed in the system, then is should be automated. If they are needed, the system must be designed for them.

5. Training Material Handlers—For decades, training in safe-lifting procedures had been advocated and conducted. Training is expected to reduce severity and frequency of injuries, develop specific material handling skills, further awareness and responsibility for one’s own safety, and improve specific physical fitness characteristics.

6. Screening Material Handlers—While training is one approach to fit the person to the job, another is to select suitable persons, i.e., screening individuals to place on strenuous jobs those who can do the jobs safely. This screening may be done either before employment, before placement on a new job, or during routine examinations during employment.

7. Ergonomic Design of Workplace and Work Task—The most effective and efficient way to reduce material handling injuries is to design equipment ergonomically, so that job demands are matched to human capabilities. Designing to fit the human can take several approaches. The most radical solution is to design our manual material movement by assigning it to machines: no people involved, no people at risk. If people must be involved, load weight and size shall be kept small, best accompanied by ergonomic design of the work task, i.e., by selecting the proper type of material handling movement and their frequency of occurrence. The location of the object with respect to the body is very important: best between hip and shoulder height, directly in front of the body so as to avoid twisting or bending the trunk. The object itself is important, of course, regarding its bulk, its pliability, and whether it can be grasped securely. Naturally, the workplace itself must be well-designed and maintained. Important aspects are proper working height; material provided in containers from which it can be removed easily; nonslip floor and a clean, orderly environment that is free of avoidable noise and climate stressors.

*Alternative Work Schedules and Shift Work*

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

When exposure cannot be reduced to permissible levels through engineering controls, as in the case of air contaminants or noise, an effort should be made to limit the employee’s exposure through administrative controls. Examples of some administrative controls are as follows:
• Arranging work schedules and the related duration of exposures so that employees are minimally exposed to health hazards
• Transferring employees who have reached their upper permissible limits of exposure to an environment where no further additional exposure will be experienced

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

c. Recognize and evaluate the following with respect to indoor air quality:
   • Temperature and humidity control
   • Proper heating, ventilating, and air conditioning (HVAC) design and maintenance
   • HVAC filter selection
   • Risk communication skills
   • Introduction of sources of air contaminants into the office environment
   • Water leaks

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

*Temperature and Humidity Control*

Invariably, something goes wrong with almost all ventilation systems. Simple troubleshooting usually involves three phases of study:
   • Characterizing complaints and gathering background data
   • Checking performance of ventilation systems and their controls
   • Measuring carbon dioxide, temperature, and relative humidity

The most common causes and sources of trouble related to ventilation systems are as follows:
   • Insufficient outside air (OA) introduced to the system
   • Poor distribution of supply air in occupied space
   • Draftiness—too much supply air or improper terminal settings
   • Stuffiness—not enough air delivery or not delivered properly
   • Improper pressure differences—doors hard to open
   • Temperature extremes—too hot or too cold
   • Humidity extremes—too dry or to humid
   • Poor filtration—dirt, bugs, or pollen in the air-delivery system
   • Poor maintenance
   • Energy conservation the number-one priority
   • Settled water in system
   • Visual evidence of slime or mold
   • Improper balance of distribution system
   • Dampers at incorrect positions
   • Terminal diffusers not at correct positions
The following list contains some common maladies or complaints and potential causes or sources of trouble:

- The temperature is too warm or too cold. Potential problems: thermostats misadjusted, supply air temperature setting too high or low, too much or too little supply air, supply diffuser blows air directly on occupants, temperature sensor malfunctioning or misplaced. Simple testing equipment: thermometer, velometer, smoke tubes.
- The air is too dry or too humid. Potential problems: humidity controls not operating correctly or undersized. Simple testing equipment: sling psychrometer.
- The air is stuffy, stagnant or there is no air movement. Potential problems: nondelivery or low delivery of air to space, filters overloaded, restrictions in ductwork, inadequate supply of OA. Simple testing equipment: thermometer, velometer, smoke tube, CO₂ meter.
- There are too many drafts. Potential problems: occupant outside of occupied zone, supply diffuser set to blow directly on occupant, occupant near open door or window, free-standing fan blowing on occupant. Simple testing equipment: velometer, smoke tube.

Proper Heating, Ventilation, and Air Conditioning (HVAC) Design and Maintenance

Correct operating procedures and maintenance of the HVAC system will ensure its continued and consistent effectiveness. Maintenance is time-consuming and expensive but has been proven to be cost-effective. Labor-intensive maintenance requires trained workers, good materials, and good management. Preventive maintenance programs usually prevent problems before they arise.

Dirt, debris, and microbiological growths in ductwork can be minimized by the following measures:

- Well-maintained filter systems (at least 40–60 percent efficiency, dust spot test
- Regular HVAC maintenance
- Good housekeeping in the occupied space
- Locating air intakes in noncontaminated locations
- Keeping all HVAC system components dry

Ducts can become both the source and the pathway for dirt, dust, and biological contaminants to spread through the building. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) 62.1-2007 and other standards suggest that efforts be made to keep dirt, moisture and high humidity from ductwork. Filters must be used and kept in good working order to keep contaminants from collecting in the HVAC system.

HVAC Filter Selection

The following is taken from Air Conditioning, Heating and Refrigeration NEWS, “A Guide to Understanding HVAC Filter Selection.”

Effective air filtration provides the primary defense for building occupants and HVAC equipment against pollutants generated within a building as well as pollutants from air drawn into a building from the HVAC system. That’s why selecting the right HVAC filter is so
critical. With today’s higher standards in filtration, it’s possible to produce cleaner, purer air and reduce indoor air quality problems.

The first step in determining the best type of HVAC filter needed is to identify the types and sizes of particular pollutants in the building. Removal of all airborne contaminants is simply not practical in most facilities, so once problematic pollutants are identified, it’s time to look at filter efficiency. Filtration efficiency defines how well the filter cleans indoor air by removing airborne particles.

Low-efficiency filters (in the range of 25 percent efficiency on 3–10 micron particles) are typically used to keep lint and dust from clogging the heating and cooling coils of an HVAC system. Medium- and high-efficiency filters (up to 95 percent efficiency on 3–10 micron particles) are typically used to remove bacteria, pollen, soot, and other small particulates.

ASHRAE has developed an HVAC filter test standard to quantify the efficiency of filters. The ASHRAE 52.2-1999 standard measures the fractional particle size efficiency (PSE) of an HVAC filter. This indicates the filter’s ability to remove airborne particles of differing sizes between 0.3 and 10 microns in diameter. A minimum efficiency reporting value (MERV) is assigned to the filter depending on the PSE in three different particle size ranges (0.3 to 1 micron, 1 to 3 microns, and 3 to 10 microns). The MERV is a numerical system based on minimum PSE. A rating of 5 is least efficient, while a rating of 16 is most efficient.

In addition to the performance factors measured under 52.2, consider these additional variables when selecting a filter:

- Moisture resistance—how high humidity and moisture affect the filter.
- Temperature limitations—how the filter performs at application temperatures.
- Flammability—how the filter performs in flammability tests. Check to see if UL Class I- or Class II-rated filters are needed to conform to local building codes.

There are many types of HVAC filters on the market today. In most buildings, the best filter choice is a medium-efficiency pleated filter (MERV 7-8), which has a large filter media area. Keep in mind that large filter media areas tend to be more cost-effective than smaller ones. Large filter media areas mean lower pressure drop and greater contaminant-holding capacity. Lower pressure drop reduces fan energy requirements, and greater contaminant-holding capacity may mean fewer filter changes.

Pleated air filters used in HVAC systems are made with a wide range of filter media, including fiberglass, polyester, paper, and synthetic nonwoven materials. Recent advances in nonwoven technologies have allowed for improvement in performance and value of synthetic filter media over the standard cotton/poly blends used for years in HVAC filters.

Unlike traditional cotton/poly media, the synthetic filter media in more modern filters can be made of thermally bonded, continuous, hydrophobic (moisture-repelling), polyolefin fibers that resist shedding and do not absorb moisture. This is important in resisting bacterial growth, and it keeps shed fibers from getting into the HVAC coils or into the air space of the building. Moreover, synthetic filter media can be manufactured without the use of chemical binders, meaning that humidity will not affect the structure of the filter. Unlike cotton/poly
filter media, which are made with a surface-loading structure, synthetic filter media can be made with a gradient density structure that provides a solid mechanical foundation to maintain high efficiency over the useful life of the filter.

The information was reprinted with permission from the Kimberly-Clark Filtration Products publication *Filtering Out Confusion – A Guide to Understanding HVAC Filter Selection*. For more information on HVAC filter technology and the International Association of Quality issues, visit www.kcfiltration.com or e-mail filtration_media@kcc.com.

**Risk Communication Skills**
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

The ability of the facility to communicate risk associated with indoor air quality is important. The facility needs to be able to inform employees of any conditions or issues that arise in air quality. Alarms are in place in many facilities to alert workers to emergency conditions. Plans and procedures should be in place to allow for personnel to notify employees of any adverse air quality conditions.

**Introduction of Sources of Air Contaminants into the Office Environment**
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

There are many sources of indoor air pollution that can affect the office environment. These include combustion sources such as oil and gas; building materials and furnishings as diverse as deteriorated asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for cleaning and maintenance; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution.

The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, such as those related to activities carried out in an office environment, release pollutants intermittently. Examples include the use of solvents and janitorial supplies in cleaning, and the use of pesticides to keep buildings pest free. High pollutant concentrations can remain in the air for long periods after some of these activities.

**Water Leaks**
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*. 


Water leaks can lead to the creation of mold in places like building basements or other underground facilities. This mold presents a biological hazard for employees. Water leaks need to be identified and corrected immediately to prevent the creation of mold. Water leaks may not be easily detectable in facility basements, partly because of the industrial nature of most facility basements, and because a water leak may not be considered a very important issue in the space.

6. **Industrial hygiene personnel shall demonstrate a working level knowledge of data collection plans for collecting data that accurately reflect exposure conditions.**

   a. **Discuss the following factors as they relate to sampling strategy:**
      - Usefulness of bulk samples
      - Degree to which operations being sampled are representative of normal conditions
      - Duration of sample
      - Level of detection
      - Exposure control methods in use during sampling
      - Sample handling
      - Data recording and management
      - Sample chain of custody
      - Statistical significance of sample
      - Exposure criteria and limits
      - Consent needs for biological samples
      - Uses and limitations of personal and area sampling

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

**Usefulness of Bulk Samples**

The addition of bulk samples can often make the difference between a successful or unsuccessful sampling effort. This is especially true where there is mixed-solvent exposure or unknown dust exposure, and when determining the silica content of dusts. The primary purpose of bulk samples is to provide the analytical laboratory with a large enough sample for qualitative and sometimes quantitative analysis. The two major types of bulk samples are bulk air and mass bulk (liquid or solid) samples.

**Bulk Air Samples**

Generally, a bulk air sample is defined as a large volume area sample collected for the purpose of qualitative analysis. A good example is multiple solvent exposure where the exact identity of the airborne solvents is unknown, e.g., painting operations. For most organic solvents, a bulk air sample consists of a charcoal tube (or whatever sorbent is called for) collected at 1 liter per minute (L/min) for an hour or more. The sample is likely to exhibit breakthrough, but this does not matter since the primary interest is in determining what substances are present rather than their exact concentrations (the latter aim is accomplished through the separate collection of proper samples). Any questions concerning how or whether or not a bulk air sample is needed should be addressed to the analytical laboratory.
prior to sampling. In the case of silica, either a bulk air or solid bulk sample (e.g., a rafter sample) or both are suggested so that enough material will be available to determine free silica content.

Bulk Liquids and Solids
The collection of bulk materials may be needed to establish the substances present in the workplace and, in some cases, to establish the relative levels of certain substances present in the raw material. A good example of the latter is the case of mixed solvent exposure when determining if a certain contaminant of interest is present, e.g., benzene. In some cases, a list of 30 solvents may be present (from MSDSs), but it is not certain which ones are present or in what proportions. This example is also true for dusts, which may exist in trace quantities.

In choosing bulk samples, the end goal must be considered. Is the interest in qualitative and/or quantitative analysis? In the case of a painting operation, it is preferred to have the bulk samples separated by contaminants of interest, i.e., the solvent fraction separate from the pigment fraction. This allows the laboratory to analyze the different portions of the paints without having to go through a lengthy separation process. The cleaner the bulk sample, the easier it will be for the laboratory to conduct the analysis. In many cases, the industrial hygienist is interested in a dirty bulk. Any information that can be given to the laboratory on what may or may not be present will help speed up the analysis. Advance consultation with the laboratory is desirable.

In choosing bulk dust samples, the sample should be representative of the airborne dust to which the workers are being exposed. Usually this is a settled dust sample collected from rafters or near the workers’ job site. In other cases, a process dust sample is chosen to determine the composition of the material before it is airborne. In cases where the choice is not clear, do not follow the adage that more is better. Bulk samples should be limited in number to optimize the laboratory’s time. A good approach, when in doubt as to what bulk samples are needed, is to collect several but to allow the laboratory to analyze only those needed to answer questions as they arise.

When shipping bulk samples, care must be taken to preserve the integrity of the samples and to follow established Department of Transportation (DOT) shipping regulations. Only 5 milliliter (mL) to 10 mL of the liquid or solid are needed, so keep bulk sample sizes small. For storage, leak-proof glass containers are best since they will not react with most chemicals. However, polyethylene containers can be used in the majority of cases. A convenient container is a 20 mL scintillation vial with a polytetrafluoroethylene-lined cap. Specific chemicals for which polyethylene containers should not be used include aromatic compounds, chlorinated hydrocarbons, and strong acids. The lids of the containers should be sealed with shrink bands or tape for further assurance against leakage. These containers should be labeled as required by DOT under their regulations (49 CFR parts 171–177). For most materials classified as flammable or poisonous, amounts up to 1 quart can be shipped by any carrier. Most bulk dusts are not covered by DOT regulations. Specific restrictions and labeling requirements should be checked prior to shipping any samples.
In the case of volatile bulk samples (and some air samples), consideration should be given to shipping the samples on dry ice or with bagged refrigerant (e.g., blue ice). Do not ship volatiles together with air samples. Again, check with the carrier you plan to use as there may be restrictions on the amount of dry ice they will accept in a package (usually 5 pounds or less is acceptable). Specific labels are usually required when dry ice is used.

**Degree to Which Operations Being Sampled Are Representative of Normal Conditions**
Sampling should be performed on operations that are representative of typical and of worst-case situations of the exposure group. Depending on the sampling results, the former may help to determine the need for employee medical surveillance, and the latter the need for the implementation of workplace controls.

**Duration of Sample**
The volume of air sampled and the duration of sampling is based on the sensitivity of the analytical procedure or direct-reading instrument, the estimated air concentration, and the OSHA standard or the TLV for that particular agent.

The duration of the sampling period should represent some identifiable period of time; for example, a complete cycle of an operation or a full shift. Often, the appropriate time period is specified in the regulatory upper limits when looking at a PEL, a full 8-hour shift of monitoring is called for. For comparison to an OSHA short-term exposure limit (STEL), 15 minute samples during a worst-case exposure scenario are required. Longer work shifts require recalculation of the relevant standard, because the total time exposure is increased.

The concentration of contaminant in the workplace is sometimes low. Direct-reading instruments and other devices used to collect samples for subsequent analysis musts collect a sufficient quantity of the sample so that the chemist doing the analysis can accurately determine the presence of minute amounts of the contaminant.

**Level of Detection**
The recommended air sample volumes are important guidelines to follow. The minimum air sample volume is the minimum amount of air needed to ensure analytical accuracy. It also allows the laboratory to analyze the sample to a concentration well below the exposure limit for the chemical. This is called the sampling method’s lower limit of detection and is the smallest amount of the chemical that the laboratory can detect.

Minimum sample volumes can be calculated if the lower limit of detection (LOD) of the analytical method is known. This can be useful if there is no listed minimum air sample volume or if the listed volume is quite large. Published values must assume worst-case conditions are present and have built-in safety factors to ensure that an adequate volume is collected. If the concentration of the contaminant can be estimated, the following formula can be used:

\[
SV = \frac{LOD}{EL \times F}
\]
where
SV = minimum sample volume
LOD = lower limit of detection
EL = exposure limit
F = anticipated fraction of the TLV in atmosphere

Establishing a maximum air sample volume is necessary to prevent breakthrough when sampling for particles. Breakthrough occurs when a significant quantity of a gas or vapor passes uncollected through a collection device. It happens when the device is saturated with the chemical or interfering chemical or the airflow rate is too fast. In particulate sampling, if the filter is overloaded it may cause the suction pump to slow down or quit, cause the loss of some of the sample as the filter is being handled in the laboratory, or make the analysis of the filter difficult. The maximum air sample volume is designed to minimize these problems.

*Exposure Control Methods in Use during Sampling*

Determinants of exposure have been studied using experimental and observational designs. In experimental designs, factors expected to influence exposure usually are selected using theoretical models or prior evidence from the hygiene literature, though production personnel and work site surveys may also provide vital clues. In many cases, the main study question is not the identification of exposure determinants, but quantification of the magnitude of effect or development of controls for known high-exposure conditions. Study conditions are altered in a controlled way under the direction of the investigator, and often in a laboratory setting.

Observational studies are conducted in actual employment settings without investigator control. Although there may be some effect due to the presence of a study team, the intent is to examine the workplace under usual operating conditions. Walkthrough surveys, process documentation, and discussions with plant personnel may provide the basis for selecting study factors, though theoretical models and existing literature also contribute.

In any case, the potential determinants identified must then be observed and documented throughout the study. Investigator control of the variety of determinants studied exists only through the selection of varied work sites, times, workers, etc.

*Sample Handling*

Sampling should be performed according to established standard operating practices to ensure that the observations are recorded consistently and that sampling plans are coordinated with the laboratory to guarantee compatibility between sampling and analysis.

*Data Recording and Management*

Accurate record keeping is essential for the correct interpretation of air-sampling results. The fundamental records include total time sampled; pump flow rate, both at the beginning and end of the sampling period; location of the area or identification of the person being monitored; and a description of the process being evaluated. In addition, sampling notes should include the engineering controls present and the location of any local or general exhaust ventilation, as well as any measurement of these taken at the time of sampling. If
other processes are located close enough to affect the sampling results, they should be described.

Sample Chain of Custody
The following is taken from the U.S. Environmental Protection Agency (EPA), *Chain of Custody Procedures for Samples and Data*.

“Chain of custody” is a legal term that refers to the ability to guarantee the identity and integrity of the sample through collection to reporting of the results.

The following are general guidelines for a chain of custody:
- Keep the number of people involved in collecting and handling samples and data to a minimum.
- Only allow people associated with the project to handle samples and data.
- Always document the transfer of samples and data from one person to another on chain-of-custody forms.
- Always accompany samples and data with their chain-of-custody forms.
- Give samples and data positive identification at all times that is legible and written with permanent ink.

Statistical Significance of Sample
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

In all sampling methods, there are systematic and random errors to consider that can affect the interpretation of results. The statistical significance of the sample can be determined by analyzing the accuracy and precision of the data collected.

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.

Precision is the degree of agreement among results obtained by repeated measurements under the same conditions and under a given set of parameters. It is possible for a measurement to be precise but not accurate, and vice versa.

Accuracy is affected by controllable sources of error. These are called determinate or systematic errors and include method error, personal error, and instrument error. Incorrect calculations, personal carelessness, poorly calibrated equipment, and use of contaminated reagents are examples of systematic error.

Precision is affected by the indeterminate or random errors, which cannot be controlled. These include intra- or inter-day concentration fluctuations, sampling equipment variations such as random pump flow fluctuations, and analytical method fluctuations such as variation in reagent addition or instrument response. These factors cause variability among the sample results. Statistical techniques are used to account for random error.

To ensure accuracy and precision, the following guidelines should be used:
• Manufacturers’ data for direct-reading instruments should be obtained whenever possible, stating the accuracy and precision of their method.
• A calibration schedule should be established and documented for all sampling equipment.
• The NIOSH Manual of Analytical Methods should be consulted for accuracy and precision of the methods chosen. When the results of the sampling are reported the NIOSH sampling method followed should be cited.
• Only laboratories that participate in industrial hygiene quality control programs, such as the one conducted by the American Industrial Hygiene Association (AIHA), should be used.

OSHA compliance officers use one-sided confidence limits (upper confidence limits [UCL] and lower confidence limits [LCL]) whenever sampling is performed. This practice recognizes that the sample measured on the employee is rarely the same as the true exposure because of sampling and analytical errors. The UCL and LCL incorporate these error factors statistically to obtain the lowest LCL and the highest UCL value that the true exposure could be, within a 95 percent confidence interval. The UCL and LCL are called one-sided confidence because they are used by both OSHA and employers to ensure that the true exposure lies on one side of the OSHA PEL, either above or below it.

Exposure Criteria and Limits
According to DOE-STD-6005-2001 an effective worker protection program encompasses the concept of prudent avoidance of worker exposure to any occupational hazard. Prudent avoidance involves minimizing the number of individuals at risk of exposure, minimizing the individual worker’s potential for exposure, and controlling all exposures to chemical and physical agents within established occupational exposure limits and keeping them as low as practical.

Consent Needs for Biological Samples
The following is taken from 45 CFR 46.

Federal regulations set out four overriding principles that are meant to apply to all consents, unless there are specific exceptions made or allowed elsewhere in the regulations:
1. Human research can proceed only with informed consent unless waived under the Federal regulations. No investigator may involve a human being as a participant in research covered by the Federal regulations without legally effective informed consent of the participant or his/her legally authorized representative.
2. The possibility of coercion in obtaining consent must be minimized. An investigator shall seek consent under conditions that provide the prospective participant or his/her representative sufficient opportunity to consider whether to participate, and that minimize the possibility of coercion or undue influence.
3. Consent must involve understandable language. The information that is given to the prospective participant or his/her representative shall be in language the participant or the representative can understand.
4. The waiver of rights is prohibited in the consent process. No informed consent, whether oral or written, may include any exculpatory language through which the
prospective participant or his/her representative is made to waive or appear to waive any of the prospective participant’s legal rights, or made to release or appear to release the investigator, the sponsor, the institution, or its agents from liability for negligence.

The Federal regulations list eight required elements of informed consent that must be met:

1. **Purpose and procedures**—Tell a prospective participant that the study involves research, explain the purpose of the study and the length of time you expect the person to participate, describe the procedures to be followed, and identify any experimental procedures.

2. **Risks**—Describe any reasonably foreseeable risks or discomforts to the prospective participant.

3. **Benefits**—Describe to the prospective participant or to others any benefits that may reasonably be expected from the research.

4. **Alternatives**—Disclose any appropriate alternative procedures or courses of treatment that might benefit the prospective participant.

5. **Confidentiality**—Tell prospective participants whether their records will be kept confidential and, if so, explain the level of confidentiality.

6. **When there is greater than minimal risk**—Tell prospective participants whether they will receive any compensation and/or medical treatments if injury occurs and, if so, what compensation or treatment will consist of, or where to obtain further information.

7. **Persons to contact**—Tell prospective participants whom to contact if they have questions about the research and their rights as a study participant, and whom to contact if they have an injury that may be related to the research.

8. **Voluntary participation, refusal, and withdrawal**—State that participation is voluntary, that refusal to participate involves no penalty or loss of benefits to which the person is otherwise entitled, and that the person may discontinue participation at any time without penalty.

**Uses and Limitations of Personal and Area Sampling**

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Personal sampling is the measurement of a particular employee’s exposure to airborne contaminants and, in theory, reflects actual exposure to the employee. It is usually done during a specific time period, often an 8-hour shift or a 15-minute period, to ensure compliance with OSHA PELs; it can therefore include times when the employee is at break or involved in activities where the contaminant of interest is not in use. It is because of the variability that it is extremely important to observe individuals being monitored and to interview them about their work, before, during and after the monitoring is done.

In personal sampling, the measurement device, or dosimeter, is placed as close as possible to the contaminant’s route of entry into the body. Even with the proper placement of the dosimeter there is no guarantee that results of personal sampling will reflect actual exposure levels. Some materials are absorbed through the skin or mucous membranes in addition to being inhaled. The release of contaminants is often not uniform, and the side of the employee
where the monitor is placed may not be the side closest to the point of release of the contaminant. The results would therefore underestimate the exposure. On the other hand, if the sampling device is placed outside a respirator or face shield, the result might overestimate the true exposure to the worker.

Personal sampling relies on portable, battery-operated sampling pumps that the employee wears throughout the sampling. This offers freedom of movement because there is no need to maintain proximity to electrical outlets. The pumps, however, can be noisy and heavy, and employees are sometimes not willing to wear them on a continuous basis. In addition, because the pumps are battery operated, they might have a variable output throughout the day, or might actually stop operating in the middle of sampling. The effective use of personal sampling pumps relies on proper calibration and maintenance and consistent supervision by well-trained professionals during the monitoring process.

Area sampling is another method used by industrial hygienists to evaluate exposure. Here, however, exposure is measured not in terms of a particular employee, but rather in terms of the ambient air concentration of a particular substance in a given area at a given period of time.

Area sampling has its disadvantages. Sampling equipment can be made rugged and reliable, but often it is not, and leaving it unattended for hours or days at a time without the supervision of a trained technician could result in no reliable data collection during a crucial period in the process. Area sampling may underestimate the exposure of a worker if the measurement probe or collection device is not in close proximity to the point of exposure at the worksite.

7. **Industrial hygiene personnel shall demonstrate a working level knowledge of sampling techniques.**

The information for this competency is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

a. **Describe the significance of instrument calibration and operation and data collection methods during sampling.**

The devices used for sampling must be calibrated to the airflow recommended in the sampling method. Calibration is critical because the determination of air sample volume depends on the flow rate and the elapsed time. There are two categories of calibration devices: primary and secondary. Primary devices provide a direct measurement of airflow. They include soap-bubble meters and spirometers. Secondary calibration devices provide indirect measurements of airflow and must be periodically calibrated with a primary calibration device. These include rotameters, wet test meters, and dry test meters.

b. **Describe how multiple exposures affect sampling techniques.**

Exposure to more than one hazardous agent may require the use of more than one sampling instrument by the same employee. More than one sampling instrument may also be required
if substances of interest require the performance of incompatible laboratory analyses. The potential for chemical interferences may also require the use of more than one sampling method and may create complications in the interpretation of results.

c. **Describe the factors (e.g., concentration, duration, frequency, placement of sample, altitude) that determine the adequacy of samples.**

In order for the sample to be of much value, the level of detection must be lower than the criterion level of interest—either the acceptable level or PEL—but preferably much lower. To ensure that the level of detection is as low as possible, the sample must contain a minimum volume of air. This, in general, requires a minimum sample duration. Duration is also important when the sample is being related to specific criterion, e.g., STELs, ceilings, etc. If possible, sampling should be performed for the entire duration of the operation being characterized. When sampling is performed for less than 8 hours because the operation was completed in that time, this fact should be noted on the sampling sheet to justify the assumption that personal exposure for the remainder of the day was zero.

The frequency of sampling may be listed in a few expanded OSHA regulations; however, normally this is dictated by professional judgment. In general, initial measurements should be taken whenever it is believed that significant exposure is possible. A second set of measurements taken sometime after the first set is also advisable as a check against possible variation in operations. If both sets of results show insignificant exposure, sampling may probably stop. Continued surveillance of workplaces is necessary to verify that new operations have not been initiated and that previously characterized operations have not changed so as to increase the potential for exposure.

d. **Describe how environmental factors (e.g., wind, rain, temperature extremes) affect the need for further sampling.**

Environmental extremes may influence instrument operation. Extreme cold, for example, may affect pumps, direct-reading instruments, and detector tube operation. High moisture or humidity resulting in condensation may also affect operation of dosimeter microphones and the reliability of sampling media. Wind may also affect noise measurement. In general, potential environmental limitations and interferences will be clearly described in the instrument operator’s manual and in standardized sampling and analytical methods, and the industrial hygienist should take note of them.

If results of monitoring are significant, periodic sampling may be required to verify the continuing adequacy of controls that are in place. Logically, the higher the previous results and the more dangerous the agent, the more frequent the subsequent sampling should be performed.

Follow-up to initial sampling may also be required if modifications in a process of controls indicate the possibility for increased exposure over earlier samples, and to verify that new engineering controls are performing as expected.
8. Industrial hygiene personnel shall demonstrate a working level knowledge of sample analysis, including the use of appropriate laboratory techniques.

a. Describe the following:
   - Selection of proper analytical instruments, techniques, and methods
   - Sensitivity and specificity of the analytical technique
   - Precision versus accuracy
   - Instrument bias
   - Interferences in sampling
   - Principles of instrument operation

The information for this KSA is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*, unless stated otherwise.

*Selection of Proper Analytical Instruments, Techniques, and Methods*

Proper advance planning minimizes sampling and measurement costs and labor and contributes to a smooth, successful survey. Many things must be considered before collecting field samples. The first step is to define sampling objectives. These may include documenting exposures in particular work settings, determining compliance/non-compliance with existing Federal or local standards or recommended exposure limits, or trying to determine the source of a problem. Sampling parameters that should be defined might include type of sample (area vs. personal), contaminant(s) to be sampled, duration of samples, potential interferences, and expected contaminant concentrations (or contaminant concentration of interest). Once these parameters are defined, then the proper analytical method and sampling media can be selected. Other general information needed to plan a survey properly includes the number of employees, the sampling strategy plan, process flow diagram, material safety data sheets on all process materials, the physical states of the substances to be sampled, and potential hazards involved in collecting and shipping the samples.

An accredited analytical laboratory should be used to conduct analysis of collected samples, and it is essential to consult with the analytical laboratory before sampling to ensure that the measurement methods available can meet the defined sampling needs. This step should be an early part of survey planning. The laboratory can also assist in choosing sampling media that are compatible with the sampling needs and the measurement methods available.

Whether through consultation with the laboratory or through reading about the specific measurement method, the sampling media will be specifically identified, e.g., pore size and type of filter, concentration and amount of liquid media required, and specific type and amount of solid sorbent. If specific brand-name products are called for, no substitutions should be made. Most sampling media are well defined through research and testing; deviations from specifications are undesirable. For example, most organic contaminants are sampled with a dual section tube containing 100 mg front and 50 mg backup sections of 20/40 mesh activated coconut shell charcoal. If larger mesh charcoal or a different type of charcoal were to be used, the sampling capacity and recovery efficiencies for the contaminant of interest might change from that specified in the method.
The physical state of the contaminant(s) being sampled may also be a factor in determining the media required. In the case of polyaromatic hydrocarbons, for example, the proper sampler consists of a membrane filter to trap particulate matter and a solid sorbent tube to trap the vapors of certain polyaromatic hydrocarbons so that total collection is assured.

The sampling pump used to collect the sample must also be compatible with the sampling needs and the media used. Specifically, the pump must be capable of maintaining the desired flow rate over the time period needed using the sampling media specified. Some pumps may not be able to handle the large pressure drop of the media. This will be true for fine mesh (smaller than 40 mesh) solid sorbent tubes, small pore size filters or when attempting to take a short-term sample on a sorbent tube of a higher than normal pressure drop at a flow rate of 1 L/minute (min) or greater. As a rule of thumb, all high-flow pumps (1–4 L/min) can handle at least 3 kPa (12 inches of water) pressure drop at 1 L/min for 8 hours. Some pumps can handle up to 7.5 kPa (30 inches of water) pressure drop at flows up to 2 or 3 L/min. Most low-flow pumps (0.01 to 0.2 L/min) can handle the pressure drops of available sorbent tubes without problems except that the nominal flow rate may decrease for certain models. All pumps should be calibrated with representative sampling media prior to use. It is good practice to check the pump calibration before and after use each day. As a minimum, calibration should be done before and after each survey.

**Sensitivity and Specificity of the Analytical Technique**

Sensitivity is the minimum amount of contaminant that can repeatedly be detected by an instrument.

Specificity is the degree to which an instrument or detection method is capable of accurately detecting or measuring the concentration of a single contaminant in the presence of other contaminants.

**Precision versus Accuracy**

According to the National Institute of Standards and Technology (NIST), *Engineering Statistics*, precision is the degree to which the method is repeatable; accuracy is the degree to which results truly indicate the level of contaminant.

**Instrument Bias**

According to NIST, *Engineering Statistics*, accuracy is a qualitative term referring to whether there is agreement between a measurement made on an object and its true (target or reference) value. Bias is a quantitative term describing the difference between the average of measurements made on the same object and its true value. In particular, for a measurement laboratory, bias is the difference (generally unknown) between a laboratory’s average value (over time) for a test item and the average that would be achieved by the reference laboratory if it undertook the same measurements on the same test item.

**Interferences in Sampling**

According to the U.S. Department of Labor, OSHA, *Evaluation Guidelines for Surface Sampling Methods*, interferences to the sampling procedure may manifest themselves in such a manner that collection, retention, recovery or stability of the analyte on the sampler is
impaired. If any substance has the ability to alter the final concentration of analyte found, it can be considered an interference. An interference can be a modification of the analyte or analyte signal during a specific portion of the analysis, a reaction with the medium, or an alteration of the collection efficiency.

Principles of Instrument Operation

The variety of types of direct-reading methods available is large and expanding, including detector tubes (both short- and long-term), aerosol monitors, integrating passive monitors for certain gases, and portable instrumentation for gas chromatography or infrared spectroscopy. Many direct-reading instruments now used for personal or area measurements have evolved from laboratory or process control instruments. Some of the considerations (i.e., specificity and sensitivity) for the use of direct-reading methods for quantitative determinations are similar to those for classical filter or sorbent methods. In many cases, direct-reading instruments, which are physically small and portable, qualify as personal sampling devices. These offer additional advantages over classical methods by reducing labor and analytical costs, and may be the methods of choice when instantaneous results are important, even at the expense of some degree of sensitivity or specificity. Manufacturers’ instructions should be followed in the calibration and use of these devices. Because of the severe conditions to which direct-reading instruments may be subjected, performance checks and preventive maintenance on a periodic basis or before each use are very important. Many direct-reading instruments are powered by nickel-cadmium batteries which can fail to provide a full charge over the full sampling period unless frequently or fully discharged and recharged several times just prior to use. The additional responsibility of field calibration of direct-reading instruments falls on the field sampling personnel.

b. Discuss laboratory data recording requirements.

The following is taken from DOE-STD-6005-2001.

Monitoring/sampling data record: at a minimum, should include the following types of information:

- Unique identifiers—keyed to but different from personal identifiers - for each employee sampled or, where representative monitoring is performed, for all employees represented by the monitoring results. Identifiers must not compromise personal privacy.
- Type, location, date, duration, and number of samples taken; sample identification numbers and sample chain of custody record; sampling instrument calibration data or reference links to same.
- Sampling and analytical methods and protocols used.
- Applicable sampling and analytical error.
- Measurement confidence limits (per statistical assumptions/analysis).
- Analytical laboratory used.
- Applicable occupational exposure limits/industrial hygiene standards.
- Supporting data and assumptions.
- Calculated or estimated worker exposure level(s) relative to applicable occupational standards. Note: Where personal protective equipment, such as respirators, hearing
protectors, etc., was used by workers to attenuate exposures, the documented record should report the measured or estimated, unattenuated level(s) of potential personal exposure, along with the type and protection/attenuation factor of the PPE worn.

c. Discuss the fundamentals of operating analytical equipment, including zeroing and the use of standards.

The following is taken from the Food and Agriculture Organization of the United Nations, FAO Corporate Document Repository, Quality of Analytical Procedures.

All activities associated with analytical procedures are aimed at one target: the production of reliable data with a minimum of errors. In addition, it must be ensured that reliable data are produced consistently. To achieve this an appropriate program of quality control (QC) must be implemented. Quality control is the term used to describe the practical steps undertaken to ensure that errors in the analytical data are of a magnitude appropriate for the use to which the data will be put. This implies that the errors (which are unavoidably made) have to be quantified to enable a decision whether they are of an acceptable magnitude, and that unacceptable errors are discovered so that corrective action can be taken. Clearly, quality control must detect random and systematic errors. The procedures for QC primarily monitor the accuracy of the work by checking the bias of data with the help of (certified) reference samples and control samples and the precision by means of replicate analyses of test samples as well as of reference and/or control samples.

Calibration of instruments (including adjustment) in the present context are also referred to as standardization. For many measuring techniques calibration graphs have to be constructed. The technique is simple and consists of plotting the instrument response against a series of samples with known concentrations of the analyte (standards). In practice, these standards are usually pure chemicals dispersed in a matrix corresponding with that of the test samples. By convention, the calibration graph is always plotted with the concentration of the standards on the x-axis and the reading of the instrument response on the y-axis. The unknowns are determined by interpolation, not by extrapolation, so that a suitable working range for the standards must be selected. In addition, it is assumed that the working range is limited to the linear range of the calibration graphs and that the standard deviation does not change over the range, but usually imply statistical problems.

Because normally the standard deviation is not constant over the concentration range, this difference in error should be taken into account. This would then yield a weighted regression line. The gain in precision is usually very limited, but sometimes the extra information about the error may be useful.

In several laboratories calibration graphs for some analyses are still adequately plotted manually and the straight line (or sometimes a curved line) is drawn with a visual best fit, e.g. for flame atomic emission spectrometry, or colorimetry. However, this practice is only legitimate when the random errors in the measurements of the standards are small: when the scattering is appreciable the line-fitting becomes subjective and unreliable. Therefore, if a calibration graph is not made automatically by a microprocessor of the instrument, the
following more objective and also quantitatively more informative procedure is generally used

The proper way of constructing the graph is essentially the performance of a regression analysis i.e., the statistical establishment of a linear relationship between concentration of the analyte and the instrument response using at least six points. This regression analysis (of reading y on concentration x) yields a correlation coefficient r as a measure for the fit of the points to a straight line by means of least squares).

Warning. Some instruments can be calibrated with only one or two standards. Linearity is then implied but may not necessarily be true. It is useful to check this with more standards.

For QC a calibration should always include measurement of an independent standard or calibration verification standard at about the middle of the calibration range. If the result of this measurement deviates alarmingly from the correct or expected value (say > 5%), then inspection is indicated.

Such an independent standard can be obtained in several ways. Most usually it is prepared from pure chemicals by another person than the one who prepared the actual standards. Obviously, it should never be derived from the same stock or source as the actual standards. If necessary, a bottle from another laboratory could be borrowed.

In addition, when new standards are prepared, the remainder of the old ones always have to be measured as a mutual check.

After calibration of the instrument for the analyte, a batch of test samples is measured. Ideally, the response of the instrument should not change during measurement (drift or shift). In practice this is usually the case for only a limited period of time or number of measurements and regular recalibration is necessary. The frequency of recalibration during measurement varies widely depending on technique, instrument, analyte, solvent, temperature and humidity. In general, emission and atomizing techniques are more sensitive to drift (or even sudden shift: by clogging) than colorimetric techniques. Also, the techniques of recalibration and possible subsequent action vary widely. The following two types are commonly practiced.

Step-wise correction or interval correction

After calibration, at fixed places or intervals a standard is measured. For this, often a standard near the middle of the working range is used (continuing calibration standard). When the drift is within acceptable limits, the measurement is continued. If the drift is unacceptable, the instrument is recalibrated and the previous interval of samples remeasured before continuing with the next interval. The extent of the acceptable drift depends on the kind of analysis but in soil and plant analysis usually does not exceed 5 percent. This procedure is very suitable for manual operation of measurements. When automatic sample changers are used, various options for recalibration and repeating intervals or whole batches are possible.
Linear correction or correction by interpolation

Here, too, standards are measured at intervals, usually together with a blank and possible changes are processed by the computer software that converts the past readings of the batch to the original calibration. Only in case of serious mishap are batches or intervals repeated. A disadvantage of this procedure is that drift is taken to be linear whereas this may not be so. Analytical equipment with automatic sample changers often employ variants of this type of procedure.

A blank or blank determination is an analysis of a sample without the standard, or an analysis without a sample, i.e. going through all steps of the procedure with the reagents only. The proper analysis of blanks is very important because:
- In many analyses sample results are calculated by subtracting blank readings from sample readings.
- Blank readings can be excellent monitors in quality control of reagents, analytical processes, and proficiency.
- They can be used to estimate several types of method detection limits.

Signals of blank analyses generally are not zero. In fact, blanks may found to be negative. This may point to an error in the procedure: e.g. for the zeroing of the instrument an incorrect or a contaminated solution was used or the calibration graph was not linear. It may also be due to the matrix of the solution (e.g. extractant), and is then often unavoidable. For convenience, some analysts practice forcing the blank to zero by adjusting the instrument. Some instruments even invite or compel analysts to do so. This is equivalent to subtracting the blank value from the values of the standards before plotting the calibration graph. From the standpoint of quality control this practice must be discouraged. If zeroing of the instrument is necessary, the use of pure water for this is preferred. However, such general considerations may be overruled by specific instrument or method instructions. This is becoming more and more common practice with modern sophisticated hi-tech instruments. Whatever the case, a decision on how to deal with blanks must be made for each procedure and laid down in the standard operating procedure concerned.

d. Discuss the following laboratory concerns and their effect on sample analysis.
- Quality assurance
- Chain of custody (samples and results)
- Equipment maintenance
- Laboratory management
- Laboratory certifications
- Training

Quality Assurance

According to DOE-STD-1112-98, the key to a properly functioning organization is an ongoing quality assurance (QA) program. A QA program is an organization’s internal system of procedures and practices to ensure the quality of its laboratory services. A QA manual or QA plan shall document this program. The QA manual or plan shall be sent to the performance evaluation program administrator prior to the on-site assessment in order to
verify that it meets the criteria. To qualify for accreditation, a laboratory shall demonstrate during the onsite assessment adherence to the written QA program or plan.

*Chain of Custody*

The following is taken from the U.S. EPA, *Chain of Custody Procedures for Samples and Data*.

“Chain of custody” is a legal term that refers to the ability to guarantee the identity and integrity of the sample through collection to reporting of the results.

The following are general guidelines for a chain of custody:

- Keep the number of people involved in collecting and handling samples and data to a minimum.
- Only allow people associated with the project to handle samples and data.
- Always document the transfer of samples and data from one person to another on chain-of-custody forms.
- Always accompany samples and data with their chain-of-custody forms.
- Give samples and data positive identification at all times that is legible and written with permanent ink.

*Equipment Maintenance*

The following is taken from DOE-STD-1112-98.

The laboratory shall maintain a preventive maintenance program for equipment used in measurement systems or quality control checks.

When equipment used for measurements or quality control is subject to change due to use or the passage of time, it shall be calibrated periodically. Calibration is performed by measurements with a certified source, a derived source traceable to the National Institute of Standards and Technology, or with a transfer reference standard. For direct radiobioassay, recalibrations shall be performed with the appropriate calibration and source geometries, or with derived source calibration phantoms. However, calibration checks of instrument performance can be performed without using the DOE laboratory accreditation program’s phantom geometries.

*Laboratory Management*

The following is taken from DOE-STD-6005-2001.

On an annual basis, management should perform and document a self-assessment to ensure the effectiveness of the implementation of industrial hygiene practices and to ensure quality. Such self-assessments should include reviews of:

- the adequacy and use of industrial hygiene resources;
- all exposure assessment records, including medical exposure data, audiometric testing records, illness and injury logs and supporting information, and any other records relevant to the maintenance of industrial hygiene functions;
- compliance with applicable industrial hygiene requirements and established performance measures;
success in receiving and responding to employee occupational health concerns;
industrial hygiene evaluation records to assess progress in abating health hazards;
all required written programs that include industrial hygiene elements (e.g., the hazard communication program and respiratory protection program);
training program effectiveness.

Management should correct any deficiencies identified by the program self-assessment in a timely manner.

To support health surveillance activities, management should maintain the following records and supporting documentation in a manner that permits ready retrieval of information:

- Drawings and/or written descriptions of operations, processes, and control systems
- Inventories of hazards
- Exposure assessment data
- Industrial hygiene evaluation reports, including all records of corrective actions

**Laboratory Certifications**

The following is taken from the American Industrial Hygiene Association, *2008 Laboratory Accreditation Policy Revision*.

The primary purpose of the American Industrial Hygiene Association (AIHA) Laboratory Quality Assurance Programs (LQAP) is to establish and maintain the highest possible standards of performance for laboratories analyzing samples to support the evaluation of occupational and environmental exposures to hazardous agents. Laboratories that comply with the elements of this program operate a quality system that meets the requirements of the International Organization for Standardization (ISO) Standard ISO/IEC 17025. This standard incorporates the principles of ISO 9001 that are relevant to the scope of testing services addressed by the laboratory.

The AIHA laboratory accreditation programs are recognized by the National Cooperation for Laboratory Accreditation. The AIHA programs are managed and conducted in full compliance with ISO/IEC 17011.

The AIHA Laboratory Accreditation Programs achieve and maintain the highest level of quality in their programs through the following steps:

1. Requiring the laboratory seeking accreditation to operate a laboratory in which sampling and testing procedures are performed with adequate controls by well-qualified personnel using appropriate equipment and methods. High standards of practice are encouraged and maintained through conformance with established accreditation criteria, education, proficiency testing, and onsite assessments.
2. Maintaining an ongoing surveillance of laboratories participating in the LQAP using criteria defined by specific program requirements.
3. Auditing accredited laboratories in order to ensure compliance with requirements and standards of the LQAP.
4. Recognizing compliance with standards by issuing certificates of accreditation for a period of 2 years in the name of the AIHA.
5. Adding, as needed, sample matrices, components, and new technologies for existing programs to serve the needs of the laboratory community.
6. Establishing, as needed, additional quality analytical programs to serve the specific needs of the laboratory community. New programs are initiated under the direction of the AIHA Analytical Accreditation Board.

Training

Training is provided through the National Laboratory Training Network (NLTN), a collaborative training system of the Association of Public Health Laboratories and the Centers for Disease Control and Prevention (CDC). Its mission is to improve laboratory practice of public health significance through quality continuing education.

The NLTN consists of four regional offices located in public health laboratories, staffed by laboratory training specialists who work closely with the state public health laboratory training personnel, CDC education specialists, and subject matter experts to identify and fulfill training needs. The NLTN conducts training needs assessments, develops and delivers quality, cost-effective training in a variety of formats. Although generally geared toward laboratorians, courses are also designed to target other healthcare workers, such as epidemiologists, nurses, infection control practitioners, physicians, and public health sanitarians.

e. Discuss the value and limitations of sampling during indoor air quality investigations for the following:
   - Environmental conditions
   - Chemical exposure
   - Bioaerosols

Environmental Conditions

The following is taken from ASHRAE Standard 55-2004.

Earlier versions of this standard were based on the assumption of a well-mixed and uniformly conditioned environment. Under-floor air distribution (UFAD) systems, however, usually involve greater variability of thermal conditions over both space and time. The effect of providing occupant-control has not been fully taken into account, although it is well established that occupants will tolerate greater fluctuations in environmental conditions if they have control over them. The rather strict air velocity limitations that were specified in the previous version of Standard 55 were incompatible with the increased local air velocities that are possible with UFAD and task/ambient conditioning (TAC) systems. ASHRAE Standard 55-1992 was revised to allow higher air velocities than the previous version of the standard if the occupant has control over the local air speed.

Standard 55-1992 also specifies allowable air speeds as a function of air temperature and turbulence intensity with the objective of avoiding unwanted drafts when the occupant has no direct local control. The draft avoidance limits are solidly based on laboratory data for temperatures below 23 °C (73.5 °F). At warmer temperatures, however, occupants will desire additional cooling, and increased air movement (and turbulence) is an easy way of achieving...
such direct occupant cooling. Standard 55-1992 allows these velocity limits based on turbulence intensity level to be exceeded if the occupant has control over the local air speed.

In the recently revised Standard 55-2004, the benefits of providing personal control of operable windows to building occupants has been added through the inclusion of an adaptive model of thermal comfort (based on field observations in naturally ventilated buildings). When thermal conditions in a building are regulated primarily by the occupants through opening and closing of the windows, the adaptive model allows a wider range of operative temperatures to be considered as acceptable thermal conditions. The adaptive model acknowledges that people who know they have control are more accepting of, and in fact prefer a wider range of, temperatures, making it easier to satisfy their comfort preferences.

The following is taken from ASHRAE Standard 62.1-2007.
Standard 62.1-2007 provides guidelines for the determination of ventilation rates that will maintain acceptable indoor air quality. Currently under continuous maintenance, the revised version of Standard 62 is expected to allow some adjustment in ventilation rates based on the ventilation effectiveness of the air distribution system. Mixing-type air distribution systems can at best achieve a perfectly mixed space, defined to have a ventilation effectiveness, or an air change effectiveness (ACE), of 1.0 as determined in accordance with ASHRAE Standard 129. By definition, mixing-type systems cannot provide preferential ventilation (ACE > 1) in which some credit could be obtained for improved ventilation effectiveness at the breathing level in the space. In the new version of Standard 62, guidance will be given on how to determine an adjusted minimum outside air ventilation rate. This rate would be calculated by dividing the ACE for mixing systems (1.0) by the ACE for the particular system under consideration. If a UFAD system can be shown (through measurement or other prescribed method) to provide an ACE greater than 1.0, then a reduced ventilation rate could be implemented.

Standard 62.1-2007 sets minimum ventilation rates for office space and conference rooms at 9.4 L/second (20 cubic feet per minute [cfm]) per person, and for reception areas at 7.1 L/s (15 cfm) per person. In the design and operation of a UFAD or TAC system containing a large number of occupant-controlled supply modules, some means must be provided to ensure that minimum ventilation rates are maintained, even when people choose to turn off their local air supply.

Chemical Exposure
The following is taken from New Jersey Department of Health and Senior Services, Division of Epidemiology, Environmental and Occupational Health, *Controlling Chemical Exposure: Industrial Hygiene Fact Sheets.*

Exposure limits have been set for about 700 chemicals; they have not been set for many thousands of other chemicals. The lack of an exposure limit does not mean a chemical is harmless or non-toxic.

There are many gaps in science’s knowledge of chemical toxicity and routes of exposure. Air sampling results are compared against exposure limits to evaluate how much improvement in
controls is needed. Some of the exposure limits apply to the average exposure over a whole work day of 7 to 10 hours. Other exposure limits apply to short term exposures of 15 to 30 minutes. Some chemicals have a notation indicating that they may be absorbed through the skin as well as inhaled.

Many exposure limits are not completely safe because they are based on incomplete scientific information. The OSHA limits consider economic and technical feasibility as well as health effects.

_Bioaerosols_

The following is taken from the NIOSH _Manual of Analytical Methods._

Bioaerosol monitoring is a rapidly emerging area of industrial hygiene. Bioaerosol monitoring includes the measurement of viable (culturable and nonculturable) and nonviable microorganisms in both indoor (e.g., industrial, office or residential) and outdoor (e.g., agricultural and general air quality) environments. In general, indoor bioaerosol sampling need not be performed if visible growth is observed. Monitoring for bioaerosols in the occupational environment is one of the many tools the industrial hygienist uses in the assessment of indoor environmental quality, infectious disease outbreaks, agricultural health, and clean rooms. Contamination (microbial growth on floors, walls, or ceilings, or in the HVAC system) should be remedied. If personnel remain symptomatic after remediation, air sampling may be appropriate, but the industrial hygienist should keep in mind that false negative results are quite possible and should be interpreted with caution. Other exceptions for which bioaerosol sampling may be appropriate include epidemiological investigations, research studies, or in situations indicated by an occupational physician and/or immunologist.

9. **Industrial hygiene personnel shall demonstrate an expert level knowledge of the analysis and interpretation of sample results.**

   a. Discuss how the following are used in the analysis of sampling results:
      - Mathematical and statistical computations
      - Units and conversions

The following is taken from Hazardous Chemical Substances Regulations, 1995, Annexure 1, _Applying Occupational Exposure Limits._

_Mathematical and Statistical Computations_

One of the most important objectives of any industrial hygiene program is to accurately assess employees’ occupational exposure to airborne contaminants, where necessary, by exposure measurements. The use of statistics in this assessment process is necessary because all measurements of physical properties contain some unavoidable random measurement error. That is, because of the effect of random measurement errors, any exposure average for an employee calculated from exposure measurements is only an estimate of the true exposure average.

Statistical computations begin with a statistical population. A statistical population is an entire class of items about which conclusions are to be drawn. Usually it is impossible to take
measurements on all items in the population. Thus, measurements are usually taken on several items constituting a statistical sample drawn from the population. The findings from the sample are generalized to obtain conclusions about the whole population. After taking measurements on items on the statistical sample, the measurements can be ranked in groups either in a table or graphically. One then recognizes that the measurements have some distribution.

The next step in data reduction is finding where the measurements are centered. There are several statistical measures of central location, or central tendency. Two common measures are arithmetic mean and geometric mean. Lastly, how the measurements are distributed about the center value is determined. Several measures of dispersion give an idea of the scatter or variation of the measurements. Three common measures of dispersion are the geometric standard deviation, the normal standard deviation, and the coefficient of variation.

In industrial hygiene, a sample usually consists of an airborne contaminant collected on a physical device. Industrial hygiene sampling is usually performed by drawing a measured volume of air through a filter, sorbent tube, impingement device, or other instrument to trap and collect the airborne contaminant.

Computations related to industrial hygiene analysis are available in NIOSH publication 77-173, Occupational Exposure Sampling Strategy Manual.

**Units and Conversions**

The following is taken from Hazardous Chemical Substances Regulations, 1995, Annexure 1, Applying Occupational Exposure Limits.

Use of metric measurement standards in the United States has been authorized by law since 1866. In 1988, Congress enacted legislation to establish the metric system as the preferred system of weights and measures for all domestic trade and commerce. This legislation also required the use of metric measurement standards in all Federal activities. On July 25, 1991, the president issued Executive Order 12770, which reiterated the order to implement the metric system “as the preferred system of weights and measures for United States trade and commerce.” This executive order directed all Federal agencies to implement “metrification” to the extent economically feasible by September 30, 1992.

OSHA’s safety compliance operations and industrial hygiene efforts have an advantage in metrification because the biological, chemical, and physical sciences have long used the metric system. Students of these subjects have been using metric weights and measures along with daily use of the English system of measures for decades. TWAs, PELs, and sampling and reporting forms all make use of the metric system.

In occupational exposure limits, concentrations of gases and vapors in air are usually expressed in ppm, a measure of concentration by volume, as well as in milligrams per cubic meter of air (mg/m³), a measure of concentration by mass. In converting from ppm to mg/m³, a temperature of 25 °C and an atmospheric pressure of 101.325 kPa (760 Torr, 1 atmosphere, 14.696 psi) are used. Concentrations of airborne particles (fume, dust, etc.) are usually expressed in mg/m³. In the case of dust, the limits refer to the total inhalable fraction unless
specifically indicated as referring to the respirable fraction. In the case of a man-made mineral fiber, the limit is expressed as fibers per milliliter of air (fibers/mL).

b. Discuss how the following affect the significance of exposures:
   - Selection of exposure criteria (e.g., action levels)
   - Individual susceptibility to identified hazards
   - Importance of non-occupational exposures
   - Other occupational exposures
   - Biological sampling results
   - Worker population demographics (e.g. effect of aging on hearing acuity)
   - Confounding factors and additive effects of multiple exposures, synergistic or potentiating conditions

Selection of Exposure Criteria
According to 29 CFR 1910.1450, exposure criteria or action level means a concentration designated in 29 CFR 1910 for a specific substance, calculated as an 8-hour TWA, which initiates certain required activities such as exposure monitoring and medical surveillance.

Individual Susceptibility to Identified Hazards
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Individual susceptibility is often underestimated because the majority of persons working with potentially infectious material are healthy. The risk assessments and biosafety levels recommended by the CDC presume a population of immunocompetent workers. Employees working with infectious agents can be put at increased risk of infection because of a variety of medical conditions such as diseases, allergies, inability to receive particular vaccines, and pregnancy or by taking drugs that alter individual defenses.

Conditions that alter individual defenses at body surfaces or impair the functioning of the immune system may put a worker at risk for certain infections. Skin disorders such as chronic dermatitis, eczema, and psoriasis leave a worker without an intact skin barrier against infection.

The development of allergies to protein such as biological products from raw plant and animal materials also present a risk to employees. If an employee cannot be immunized because of an allergy to a constituent of a vaccine, the safety of that person may be compromised. A higher level of work practices and personal protective equipment may provide the required level of protection for such a worker. All of these factors must be recognized and evaluated in relation to an employee’s potential exposure. Decisions should be made on a case-by-case basis, with input from the employee, the employee’s physician, institutional management, and an occupational health service professional.

Importance of Non-occupational Exposures
The following is taken from NIOSH *Worklife Initiative, Program Description*. 
The overall health of workers is influenced by factors inside and outside the workplace: stress at work and home, physical and chemical exposures, energy imbalance from diet and limited exercise, smoking, medications, hypertension, and alcohol use, to name a few. Research has confirmed the profound importance of social, cultural, economic, and genetic influences as well as access to health care on health and health-preserving behaviors. The effects of these many factors cannot be artificially divided between “at work” and “non-work.” Just as workplace conditions can affect health and well-being at home and in the community, exposures, activities, and conditions outside of working hours can substantially determine health, productivity, and responses to exposures during work.

Despite the obvious on- and off-work interactions and effects, there has been a long-standing separation in the public health and employment communities between those interested in control of health risks and hazards from work and those focused on individual and community health risk reduction outside the workplace. The occupational health community has seen efforts at generic health promotion and disease prevention in the workplace at best as drawing needed resources from occupational health protection strategies, and at worst involving victim blaming and distracting attention from the occupational health needs of workers. There has been concern that a narrow focus on health promotion will deflect employers from their legal responsibilities to provide workplaces free of recognizable hazards. On the other hand, others concerned with promoting health and controlling health care costs have seen the workplace as a convenient and valuable venue to provide important services to a worthy priority population, resulting in overall health improvement.

A new approach, reflecting the growing appreciation of the complexity of influences on worker health and the interactions between work-based and non-work factors is needed. Some scientists have explored the benefits of workplace-based interventions that take coordinated or integrated approaches to diminishing health threats to workers in and out of work. A growing body of evidence indicates that these approaches are more effective in protecting and improving worker health and well-being than traditional, isolated programs.

Other Occupational Exposures
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

For other occupational exposures, control procedures shall be implemented that are consistent with the current ACGIH *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*. Controls will depend on the physical and chemical properties of the material, how it will be handled (specifically if the material will be handled in such a way that it could be dispersed into the air or spread on surfaces), the quantity involved, and the duration and number of potential exposures.

Biological Sampling Results
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Environmental samples are used qualitatively and quantitatively to
- identify biological agents and understand the environmental conditions that lead to their presence indoors,
- demonstrate possible pathways by which bioaerosols and gases and vapors of biological origin may travel from environmental sources to workers, and
- measure worker exposure to biological agents and learn about exposure-response relationships.

Worker Population Demographics
The following is taken from Occupational Hazards, *Safety Issues on the Table*.

Politics aside, a common concern for 2007 and beyond is the changing demographics of the U.S. work force. These concerns fall into two major categories: the graying of the U.S. work force and the growing number of Hispanics and other non-English-speaking immigrants in the work force.

At the National Safety Council’s 2005 Congress and Expo in Orlando, Florida, Secretary of Labor Elaine Chao noted that the aging of the U.S. work force “has implications for just about every major public policy issue, including health and safety.”

In addition to dealing with an aging worker population, many safety and health professionals in 2007 will be charged with the task of ensuring the safety of a growing contingent of Hispanic and other non-English-speaking workers. According to the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries for 2005, there were 917 workplace deaths among Hispanic or Latino workers—the highest death toll reported for Hispanics since BLS launched the census in 1992.

Confounding Factors
The following is taken from STATS at George Mason University, *What are Confounding Factors and How Do They Affect Studies*?

Risk factors that affect the results of a study are called confounding factors. They play an extremely important role in the design and statistical analysis of any study involving human behavior, both biological and social.

Confounding factors can have a huge impact on the results of controlled and observational studies. Researchers do not always consider the impact of these factors, especially when the research itself is not done by professionals.

While there are standard statistical techniques to adjust for confounding factors, at times it is not clear whether some factor is confounding or not. In a recent controversy over obesity, the CDC published a study indicating that slightly overweight people live longer than thin people. The Harvard School of Public Health and the American Cancer Society later criticized the results, noting that more of the thin people were sick (and were thin because they were sick) than the overweight people.

In this case, illness was a confounding factor that had not been considered by the CDC. While it may seem obvious in retrospect, it can, when designing a study, be difficult to
anticipate every possible confounder. And even if it had been brought to the attention of the CDC that there were more sick people among the group of thin people, the researchers may have wondered whether the thinness caused the illness, rather than the other way around. If people were sick because they were thin, then illness would not be a confounding factor.

Confounding factors can be accounted for by using statistical techniques. Typical confounders include age, gender, smoking, and income, but there may be many other (possibly subtle or controversial) factors.

Combined Effects
The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

At present, very little is known about how the body integrates two different types of stress and the resultant strain, even if both stressors are chemicals. The usual assumption is that chemicals affecting different organs or tissues should be considered independently, whereas those that affect the same organ or tissue should be considered jointly because they may produce additive or synergistic effects.

Synergism is known to occur with certain exposures. The best known synergistic effect is that of smoking combined with asbestos exposure. The risk of lung cancer increases greatly beyond that expected from adding the risks together. Similarly, in vitro studies of organophosphorus pesticides have shown that a combined exposure to malathion and diazinon results in cholinesterase inhibition significantly greater than a mere summation of the effects would predict.

Other research has focused on less obvious combined effects. One study looked at the effects of different chemicals on hearing and found that trichloroethylene, arsenic, heavy metals, organotin compounds, and manganese all caused some degree of hearing loss or audiometric abnormalities in occupationally exposed workers. Carbon disulfide interacted with noise to cause sensorineural hearing loss: toluene and noise acted synergistically to increase the incidence of hearing loss. Another study looking at the combined effects of chemicals commonly found at hazardous waste sites, saw both synergistic and antagonistic interactions.

In most workplace exposure assessments, chemical, physical, biological and psychological hazards are present at the same time. For example, the process of tunneling can involve simultaneous exposures to high atmospheric pressure, dust, noise, heat, high humidity, carbon monoxide, and physical safety hazards. An assessment of strain produced by any one of these stressors would be complicated by the presence of any or all of the others.

c. Discuss the role that standards, guidelines, and legal requirements have on analyzing and interpreting results.

The following is taken from DOE-STD-6005-2001.

Interpretation of all monitoring/sampling results and other measurements relating to the worker exposure assessment, relative to established standards and rationale for estimates of exposure levels
should be provided as appropriate. Personal exposure levels should be expressed in appropriate measurement parameters to compare against recognized occupational exposure standards, e.g., 8-hour TWA concentration, short-term exposure level, peak or ceiling concentration, or average sound pressure level, dBA.

d. Discuss the methods of sampling and their limitations for the following:
   - Heat stress (ambient conditions and physiological monitoring)
   - Ergonomic hazards
   - Bioaerosols

Heat Stress
Refer to competency statement 2.b for a discussion of heat stress.

Ergonomic Hazards
The following is taken from the National Safety Council, Fundamentals of Industrial Hygiene.

In the traditional system concept of engineering psychology, the human is considered a receptor and processor of information or energy, who then outputs information or energy. Input, processing, and output follow each other in sequence. The output can be used to run a machine, which may be a simple hand tool or a space craft.

The actual performance of this human-technology system is monitored and compared with the desired performance. Hence, feed-back loops connect the output side with the input side. The difference between output and input is registered in a comparator, and corrective actions are taken to minimize any output/input difference. In this system, the human controls, compares, makes decisions, and corrects.

Affordance is the property of an environment that has certain values to the human. 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 or human engineering provides affordances.

Traditional engineering psychologists describe our activities as a linear sequence of stages, from perception to decision to response. Research is done separately on each of these stages, on their substages, and on their connections. Such independent, stage-related information is then combined into a linear model.

Ecological psychologists believe that this linear model is invalid; they consider human perception and action to be based on simultaneous rather than sequential information. This concept requires fundamentally new models of information, cognition, and performance assessment. Yet, current behavioral knowledge is still almost completely based on the traditional sequential-system concept.

Bioaerosols
The following is taken from the NIOSH Manual of Analytical Method.
Bioaerosol monitoring is a rapidly emerging area of industrial hygiene. Bioaerosol monitoring includes the measurement of viable (culturable and nonculturable) and nonviable microorganisms in both indoor (e.g., industrial, office, or residential) and outdoor (e.g., agricultural and general air quality) environments. In general, indoor bioaerosol sampling need not be performed if visible growth is observed. Monitoring for bioaerosols in the occupational environment is one of the many tools the industrial hygienist uses in the assessment of indoor environmental quality, infectious disease outbreaks, agricultural health, and clean rooms. Contamination (microbial growth on floors, walls, or ceilings, or in the HVAC system) should be remedied. If personnel remain symptomatic after remediation, air sampling may be appropriate, but the industrial hygienist should keep in mind that false negative results are quite possible and should be interpreted with caution. Other exceptions for which bioaerosol sampling may be appropriate include epidemiological investigations, research studies, or situations so indicated by an occupational physician and/or immunologist.

Most aerosol sampling devices involve techniques that separate particles from the air stream and collect them in or on a preselected medium. Impaction, filtration, and impingement are three common sampling techniques used to separate and collect the bioaerosol.

Impaction is used to separate a particle from a gas stream based on the inertia of the particle. An impactor consists of a series of nozzles (circular or slot-shaped) and a target. Perfect impactors have a “sharp cutoff” or step-function efficiency curve. Particles larger than a particular aerodynamic size will be impacted onto a collection surface while smaller particles proceed through the sampler. High velocity, inlet losses, interstage losses, and particle reentrainment affect the performance characteristics of an impactor.

Collection of particles from a nonbiological aerosol sample is most commonly achieved by filtration. Filter media are available in both fibrous (typically glass) and membranous forms. Deposition occurs when particles impact and are intercepted by the fibers or surface of filter membranes. Membrane filters are manufactured in a variety of pore sizes from polymers such as cellulose ester, polyvinyl chloride, and polycarbonate. Polymeric membrane filters lack rigidity and must be used with a support pad. The choice of a filter medium depends on the contaminant of interest and the requirements of the analytical technique.

Liquid impingers are a special type of impactor. Impingers are useful for the collection of culturable aerosols. Impingers use a liquid as the collection medium.

The particle size distribution of the bioaerosol is very important in the evaluation of the data obtained using the selected sampler. If the selected sampler does not provide particle size distribution data, then a cascade impactor should be used.

A membrane filter sampler is not appropriate for sampling culturable *E. coli* because the cells would desiccate and become either nonviable or viable but not culturable. In another example, an impactor with a *d*<sub>50</sub> of 4 µm should not be used to collect *Aspergillus niger* spores because most spores would remain entrained in the air passing through the instrument.
10. Industrial hygiene personnel shall demonstrate a working level knowledge of the methods used to educate people about how to protect themselves from health stressors.

a. Discuss the importance of the following as they relate to employee training in industrial hygiene:
   - Regulatory training and educational content requirements
   - Qualifications and credibility of course instruction
   - Audience receptivity of educational/training materials, format, and classroom conditions
   - Audience educational level and language skills
   - Bottom-line goals of the education/training being provided

Regulatory Training and Educational Content Requirements
The following is taken from DOE-STD-6005-2001.

DOE and contractor line management are required to provide worker hazard training and to encourage employee involvement. Line workers are the individuals most in contact with the hazards and, therefore, have a vested interest in the Worker Protection Program. As such, they can serve as valuable resources and problem solvers. Workers who are properly trained and allowed to contribute and implement ideas are more likely to support them since they now have a personal stake in ensuring that rules and procedures are followed. Therefore, line workers should be directly involved with, and should participate in, activities such as inspecting work sites, identifying hazards, selecting work practice controls, and serving on worker protection committees.

DOE and contractor line management shall ensure that workers are trained in
   - methods and observations that may be used to detect the presence of an occupational health hazard in the work area (e.g., the use of continuous monitoring devices and how to recognize the visual appearance or odor of hazardous chemicals when being released);
   - an understanding of the physical and health hazards of the chemicals, ergonomic stressors, and harmful physical and/or biological agents in the work area;
   - measures that workers can take to protect themselves from these hazards, including use of engineering controls, specific procedures, or other controls (such as appropriate work practices, emergency actions, and PPE);
   - details of chemical hazard communication, the Laboratory Chemical Hygiene Plan, or the Hazardous Waste Operations and Emergency Response program(s) developed by DOE or the contractor;
   - details of any applicable operations or hazard-specific training programs.

Employee training shall include
   - methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, the use of continuous monitoring devices, and the visual appearance or odor of hazardous chemicals when being released);
the physical and health hazards of chemicals in the work area;
the measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used;
the applicable details of the employer’s written chemical hygiene plan.

Qualifications and Credibility of Course Instruction

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

The Accrediting Board of Engineering and Technology requires that the faculty be of sufficient number as determined by student enrollment and the expected outcome competencies of the program. The faculty must have sufficient qualifications and must ensure the proper guidance of the program and its evaluation and development. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, applicable experience, teaching performance, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and applicable certification, registrations, or licensures.

The proposed criteria also state requirements for facilities, institutional support, and financial resources. Criteria specific to industrial hygiene programs require that they demonstrate that graduates have necessary knowledge, skills, and attitudes to competently and ethically implement and practice applicable scientific, technical, and regulatory aspects of industrial hygiene. Graduates must be prepared to anticipate, recognize, and evaluate and control exposures of workers and others to physical, chemical, biological, ergonomic and psychosocial factors, agents and/or stressors that can potentially cause related diseases and/or dysfunctions.

Audience Receptivity of Educational Training Materials, Format, and Classroom Conditions

The following is taken from The Presentation Team, *In the Beginning...Know the Audience*.

When starting on a new presentation, it’s helpful to know the audience. The more you know about the audience, the greater the likelihood of creating a presentation that is tailor-made to meet their needs. The choice of stories and examples to include will depend on who they are, where they are, and what they already know. Consider these points when preparing a presentation:

- What is the gender of the audience? More male than female? More female than male? Or is it equally balanced?
- What is the age range?
- How many people will there be?
- What do they know? What information is the audience starting with? What is their level of knowledge about the subject? You do not want to intimidate them or talk above or down to them. Have they heard it before? Do not waste their time or yours. Give them something new or a different perspective.
- Why are they here? Is the audience attending voluntarily? Is it for personal gain, or did the boss send them?
Knowing the audience can help you target your message, and having a targeted message will improve audience receptivity.

**Audience Educational Level and Language Skills**
See the discussion on audience receptivity in this competency.

**Bottom-Line Goals of the Education Training Being Provided**
According to the Center for Safety and Emergency Response Training, *Training*, educating employees on workplace hazards and controls may be done for two reasons: (1) to achieve compliance with a regulatory requirement, and (2) to provide employees with the knowledge and skills needed to recognize and control the hazards of their jobs.

b. List the fundamental assumptions of public and workplace risk communication, and explain in general both how risk should be explained to a non-technical audience and what should be avoided in risk communication.

M. Haider’s *Global Public Health Communication: Challenges, Perspectives, and Strategies* states that there are many challenges in how we communicate risk, especially risks to health. Few areas continue to stir debate more than advances in medicine and biotechnology. Stem cell research, vaccine development, and genomic manipulation are but a few of the areas under recent attack. Even public health successes that have decreased morbidity and mortality—such as vaccination, air bags, and fluoridation—have been surrounded by controversy. Scientific and health literacy require understanding, but the incremental and imprecise nature of science and experimentation that contributes to defining risk thrives on doubts, criticism, and debate, which often translate into only theoretical causality and risk. Furthermore, scientifically valid information is not absolute and may change over time. Translating theoretical (imprecise and incomplete) and changing knowledge of causality and risk has developed into its own body of knowledge called risk communication. According to a 1996 National Research Council report, risk communication emphasizes the process of exchanging information and opinion with the public.

c. Identify the potential non-occupational hazards associated with employees' lifestyle that may contribute to occupational illness.

The following is taken from *The Internet Journal of Academic Physician Assistants, The Importance of Promoting Health in the Workplace*.

As a means of reducing risk for employees, many companies over the last several decades have introduced worksite health promotion programs. Such programs have historically resulted in reduced absenteeism, increased employee retention, reduced health care costs, and employee satisfaction. Employers are charged with assisting employees in retirement planning, and now they are recognizing the need to educate employees regarding those lifestyle factors that are most likely to ensure employees reach their retirement years in good health. There is increasing evidence that health promotion and wellness programs have proven successful for many companies and employees. Most chronic diseases are associated with lifestyle practices. Among these are heart disease, cancer, and other chronic debilitating diseases such as arthritis and diabetes. Contemporary lifestyle may be an associated factor in
the development and progression of these diseases. Education regarding prevention and management of these diseases may reduce loss of life, improve quality of life, and better utilize financial resources. Additionally, screening programs for early detection and assessment of risk factors for these diseases may prove a valuable component of the educational program. Early detection reduces absenteeism, often reduces cost of treatment, and improves the prognosis.

11. **Industrial hygiene personnel shall demonstrate an expert level knowledge of personal protective equipment (PPE) programs for controlling exposure, including their use and limitations.**

   a. **Discuss when PPE is an acceptable and appropriate control mechanism.**

   The following is taken from DOE G 440.1-1A.

   When engineering and/or administrative controls have been considered and implemented and are not sufficient to fully protect the worker from a recognized hazard, PPE can be used to supplement these other controls as appropriate. PPE is acceptable as a control method:
   - to supplement engineering, work practice, and administrative controls when such controls are not feasible or do not adequately reduce the hazard;
   - as an interim measure while engineering controls are being developed and implemented;
   - during emergencies when engineering controls may not be feasible;
   - during maintenance and other non-routine activities where other controls are not feasible.

   b. **Discuss how to recognize when PPE is a necessary companion to other control measures.**

   The following is taken from DOE G 440.1-1A.

   The use of PPE can itself create significant worker hazards, such as heat stress, physical and psychological stress, and impaired vision, mobility, and communication. An example would be a worker wearing several layers of clothing (for warmth and anticontamination), a respirator, gloves, and a helmet while welding or cutting. This arrangement of PPE could prevent the worker from being aware of the environment in the event of a fire or other emergency.

   In these situations, engineering and/or administrative controls should be implemented to supplement PPE. Equipment and clothing should be selected that provide an adequate level of protection. The selection process should involve representatives of the affected safety disciplines working in concert.

   Two basic objectives of any PPE practice should be to protect the wearer from safety and health hazards, and to prevent injury to the wearer from incorrect use and/or malfunction of the PPE. To accomplish these objectives, a comprehensive PPE practice should include
hazard identification; medical monitoring; environmental surveillance; selection, use, maintenance, and decontamination of PPE; and associated training.

c. Discuss the selection, use, maintenance, limitations, and capabilities of respiratory equipment and other types of PPE (e.g., eye protection, protective clothing, personal hearing protection).

Respiratory Protection

The following is taken from DOE G 441.1-1A.

Respiratory protective equipment is used to reduce an individual’s intake of airborne radioactive materials. Each respiratory protective device is assigned a protection factor that indicates the degree of protection afforded by the respirator. Respiratory protective devices should be chosen based on the protection factor and actual or potential airborne radioactivity levels, taking into account as low as reasonably achievable considerations, other industrial hazards, and worker safety. DOE requires its respiratory protection programs to be conducted in accordance with DOE O 440.1A, Worker Protection Management for DOE Federal and Contractor Employees, which endorses the most restrictive parts of ANSI Z88.2, American National Standard for Respiratory Protection, or 29 CFR 1910.134.

An important step in selecting the proper respiratory protective equipment is determining the actual or potential concentration of airborne radioactivity in the area the individual is to enter. Air sampling shall be performed as necessary to characterize the airborne radioactivity hazard where respiratory protection against airborne radionuclides has been prescribed. Typically, grab sampling is used to determine the airborne radioactivity concentration. Real-time air monitoring may be useful in areas where substantial work is being performed and airborne radioactivity concentrations fluctuate. If the individual is entering an area where the airborne radioactivity concentration is routinely sampled and is not likely to have changed since air monitoring was last performed, previously obtained samples may be used to characterize the airborne radioactivity hazard.

When the need for air monitoring is not clear, historical data from fixed-location air sampling and real-time air monitoring should be analyzed to determine whether respiratory protection is appropriate. NUREG-1400 provides a methodology for predicting the potential intakes, which can be useful in determining the need for respiratory protection.

Eye Protection

The following is taken from ANSI Z87.1-2003.

Lenses

The new standard designates that lenses will be divided into two protection levels, basic impact and high impact as dictated by test criteria. Basic impact lenses must pass the “drop ball” test, a 1-inch-diameter steel ball is dropped on the lens from 50 inches. High-impact lenses must pass “high velocity” testing where ¼-inch steel balls are “shot” at different velocities.

- Spectacles: 150 ft./sec.
- Goggles: 250 ft./sec.
- Faceshields: 300 ft./sec.

Frames
All eyewear/goggle frames, faceshields or crowns must comply with the high-impact requirement. (This revision helps eliminate the use of “test lenses,” and ensures all protectors are tested as complete—lenses in frame—devices). After making an eye hazard assessment, employers (safety personnel) should decide on appropriate eyewear to be worn, although high impact would always be recommended.

Impact Protection Level
To identify a device’s level of impact protection, the following marking requirements apply to all new production spectacles, goggles, and faceshields. Basic impact spectacle lenses will have the manufacturer’s mark, i.e. an AOSafety product will have “AOS” and a Pyramex product will have a “P,” etc. Goggles and faceshields will have AOS and Z87 (AOS Z87). High-impact spectacle lenses will also have a plus + sign, (AOS+) or “P+” etc. All goggle lenses and faceshield windows are to be marked with the manufacturer’s mark, Z87, and a + sign (AOSZ87+).

Note: Lenses/windows may have additional markings. Shaded lens may have markings denoting a shade number such as 3.0, 5.0 etc. Special purpose lenses may be marked with “S.” A variable tint lens may have a “V” marking.

Side shield coverage, as part of the lens, part of the spectacle, or as an individual component, has been increased rearward by 10 millimeters via a revised impact test procedure. While side protection in the form of wraparound lens, integral or attached component side shield devices is not mandated in this standard, it is highly recommended. Further, OSHA does require lateral protection on eye protection devices wherever a flying particle hazard may exist, and flying particle hazards are virtually always present in any occupational environment.

Thickness Requirement
High-Impact Lenses
The standard does not have a “minimum lens thickness” requirement for high impact spectacle lenses. The previous standard required a 2-millimeter “minimum.” However, the protective advantages of wrap around lenses and the many other advancements in eyewear design have eliminated this need.

Protective Clothing
The following is taken from DOE-HDBK-1122-2009.
The basic factors that determine the type and extent of protective clothing required are
- type and form of contamination
- levels of contamination
- type of work being performed
- potential for increased levels of contamination
- the area of the body at risk
- competing hazards, i.e., asbestos, heat stress, etc.

Once the types of protection needed are established, the most efficient protective clothing must be selected from the different articles of protective clothing available for use.

The following is taken from DOE-HDBK-1122-2009.

Whole Body Protection
- Laboratory coat
  - Provides protection from low levels of contamination.
  - Only applicable when the potential for body contact with contaminated surfaces is very low.
  - Lab coats are generally worn for hands-off tours and inspections in areas with removable contamination at levels 1 to 10 times the values in table 2-2 of the Radiological Control Standard.
  - Lab coats may also be worn during benchtop, laboratory fume hood, sample station, and glovebox operations.

- Coveralls
  - Provide protection from low to moderate levels of dry contamination.
  - Protection is low when body contact with contaminated surfaces is prolonged (since contamination can be ground into the cloth).
  - Protection is low when the surface is wet.
  - Degree of protection can be increased by use of more than one pair at a time to protect the body.
  - Not effective against radionuclides with high permeation properties (gases, tritium, etc.).

- Plastic coveralls
  - Provide protection from high levels of dry contamination.
  - Provide protection from wet forms of contamination.
  - Provide limited protection from tritium and other highly permeating radionuclides being transported through the coveralls to the skin surface.

- Disposable coveralls
  - Used for work involving mixed hazards, e.g., asbestos, PCBs, etc., where reuse is not desirable.
  - Types of suits are Tyvek, Gore-Tex, etc. which provide moderate protection from radioactive contamination.
  - Can be easily torn.

Hearing Protection
According to 29 CFR 1926.101, wherever it is not feasible to reduce the noise levels or duration of exposures to those specified in table D-2, Permissible Noise Exposures, in 1926.52, ear protective devices shall be provided and used. Ear protective devices inserted in
the ear shall be fitted or determined individually by competent persons. Plain cotton is not an acceptable protective device.

**d. Discuss how the properties of absorption, adsorption, and filtration mechanisms (respiratory protection) affect the selection of PPE.**

The following is taken from NIOSH 2005-149, *NIOSH Pocket Guide to Chemical Hazards*.

Appropriate PPE such as an air-purifying respirator with a filter/cartridge may be required when working with the properties of absorption, adsorption, and filtration mechanisms.

In general, only supplied-air respirators are effective in preventing inhalation of airborne tritium. Two types of air-supplied respirators are available: self-contained breathing apparatus (SCBA) and full-face supplied air masks.

A SCBA, consisting of a full-face mask fed by a bottle of compressed air carried on the worker’s back, provides excellent protection against tritium oxide (HTO) inhalation. Because the mask provides no protection against absorption by most of the skin, the SCBA is normally reserved for emergency use only. The protection factor of 3 or more afforded by the SCBA may be adequate for some applications. A SCBA can be used as an added precaution during certain maintenance or operations that experience has shown should not result in the release of significant amounts of HTO. Nevertheless, the potential for exposure is real, and the SCBA gives the worker time to leave the area if necessary before a skin exposure occurs.

Full-face supplied-air masks are also available. Because the air is normally supplied by a fixed-breathing-air system, they are not practical for many emergency situations and, consequently, are not as popular as SCBAs. NIOSH 2005-100, *Respirator Selection*, provides a step-by-step selection process for respiratory PPE.

The selection of N-, R-, and P-series filters depends on the presence of oil particles, as follows:

- If no oil particles are present in the work environment, use a filter of any series (i.e., N-, R-, or P-series).
- If oil particles (e.g., lubricants, cutting fluids, glycerine) are present, use an R- or P-series filter.
- If oil particles are present and the filter is to be used for more than one work shift, use only a P-series filter.

An easy prompt is
  - **N** for Not resistant to oil.
  - **R** for Resistant to oil.
  - **P** for oil Proof.

Selection of filter efficiency (i.e., 95%, 99%, or 99.7%) depends on how much filter leakage can be accepted. Higher filter efficiency means lower filter leakage.

An air-purifying chemical cartridge/canister respirator is recommended that has a sorbent suitable for the chemical properties of the anticipated gas/vapor contaminant(s) and for the
anticipated exposure levels. Information on cartridges or canisters approved for use for classes of chemicals or for specific gases or vapors can be found in the NIOSH Certified Equipment List at http://www.cdc.gov/NIOSH/npptl/topics/respirators/cel/.

e. Describe the major elements of a hearing conservation program.

The following is from SLAC-1-730-OA09S-022-R000.

The standards for occupational noise exposure adopted by the DOE state that personnel without hearing protection must not be exposed to an intensity of noise exceeding 85 dBA (A-weighted decibel) based on an 8-hour TWA as measured on the A-weighted scale. This means that if personnel are working in an area where the intensity of noise exceeds an average of 85 dBA over 8 hours, the amount of time that they may work in the area without hearing protection must be reduced in relation to the amount that the noise exceeds 85 dBA. For example, if the noise in an area is measured at an average of 90 dBA over an 8-hour period, personnel may only work in that area without wearing hearing protection for a maximum of 4 hours. According to this standard, personnel may work a full 8-hour shift without hearing protection in an area where the noise level does not exceed an 8-hour TWA of 85 dBA.

OSHA regulations require that employers implement a hearing conservation program for employees exposed to high levels of sound. This program includes sound measurements, training, record-keeping, and audiometric testing.

The employer shall administer a continuing, effective hearing conservation program, as described in 29 CFR 1910.95, whenever employee noise exposures equal or exceed an eight-hour TWA of 85 dBA (slow response) or, equivalently, a dose of 50 percent.

f. Discuss limitations in the use of PPE.

The following is taken from DOE HDBK-1079-94.

Lab Coats and Coveralls

Lab coats and coveralls (fabric barriers) are worn in most tritium facilities. Lab coats are routinely worn to protect personal clothing. Coveralls are sometimes worn for added protection instead of a lab coat when the work is unusually dusty, dirty, or greasy. The protection afforded by lab coats and coveralls is minimal (except for short exposures) when tritium is airborne, but they are more effective in preventing skin contact with contaminated surfaces.

Disposable water-proof and water-resistant lab coats and coveralls have been tested at various laboratories. They are not popular for everyday use because of the cost and excessive discomfort inflicted on the worker. Most facilities prefer using ordinary open-weave fabrics for lab coats and coveralls and using an approved laundry for contaminated clothing. Some facilities have chosen to use disposable paper lab coats and coveralls, exchanging the costs associated with a laundry for the costs associated with replacement and waste disposal.
\textit{Shoe Covers}

Although shoe covers provide protection against the spread of contamination and exposure, the routine use of shoe covers in a tritium facility is usually weighed against actual need. Shoe covers can offer both a degree of personnel protection and control over the spread of contamination on floors. However, in modern facilities where tritium is largely controlled by the use of secondary containment, shoe covers may not be required. Such facilities can easily maintain a clean laboratory environment by the use of regular smear surveys and good housekeeping. Using liquid-proof shoe covers until spills are cleaned up should be considered following spills of tritium-contaminated liquids and solids to prevent the spread of local contamination.

\textit{Gloves}

In most operations, the hands and forearms of workers are vulnerable to contact with tritium surface contamination. The proper use and selection of gloves are essential.

Many factors should be considered in selecting the proper type of glove. These include chemical compatibility, permeation resistance, abrasion resistance, solvent resistance, glove thickness, glove toughness, glove color, shelf life, and unit cost. Gloves are commercially available in butyl rubber, neoprene, polyvinyl chloride (PVC) plastics, latex, etc.

The most common type of glove found in tritium laboratories is the light-weight, disposable short glove (usually made of PVC or latex) used for handling lightly contaminated equipment. Depending on the level of contamination, such gloves may be changed frequently (every 10–20 minutes), a second pair may be worn, or heavier gloves may be used instead. When using gloves for this purpose, the work should be planned so that contaminated gloves do not spread contamination to surfaces that are being kept free of contamination.

When working in a glovebox using the box gloves, disposable gloves are worn to prevent uptake of HTO contaminating the outside of the box gloves. Again, depending on the level of contamination, more than one additional pair may be required, one of which may be a longer, surgeon’s length glove.

In spite of all the precautions normally taken, workers may occasionally be contaminated with tritium. The skin should be decontaminated as soon as possible after any potential skin exposure to minimize absorption into the body. Effective personal decontamination methods include rinsing the affected part of the body with cool water and soap. If the entire body is affected, the worker should shower with soap and water that is as cool as can be tolerated. Cool water keeps the pores of the skin closed and reduces the transfer of HTO across the skin. The importance of washing the affected skin as soon as possible after contamination cannot be overemphasized. Even if gloves are worn when handling contaminated equipment or when working in contaminated glovebox gloves, it is good practice to wash the hands after removing the gloves.
g. Discuss how regulations, standards, and certification procedures affect the use of PPE.

Title 29 CFR 1910.132 provides general requirements for PPE. This section of the code includes the following.

Protective equipment, including PPE for the eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers, shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation, or physical contact.

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

All PPE shall be of safe design and construction for the work to be performed.

The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of PPE. If such hazards are present, or likely to be present, the employer shall

- select, and have each affected employee use, the types of PPE that will protect the affected employee from the hazards identified in the hazard assessment;
- communicate selection decisions to each affected employee;
- select PPE that properly fits each affected employee.

Note: Non-mandatory appendix B contains an example of procedures that would comply with the requirement for a hazard assessment.

The employer shall verify that the required workplace hazard assessment has been performed through a written certification that identifies the workplace evaluated, the person certifying that the evaluation has been performed, and the date(s) of the hazard assessment. The document must be clearly identified as a certification of hazard assessment.

Defective or damaged PPE shall not be used.

The employer shall provide training to each employee who is required by this section to use PPE. Each such employee shall be trained to know at least

- when PPE is necessary;
- what PPE is necessary;
- how to properly don, doff, adjust, and wear PPE;
- the limitations of the PPE;
- the proper care, maintenance, useful life, and disposal of the PPE.

Each affected employee shall demonstrate an understanding of the training specified in 29 CFR 1910.132 and the ability to use PPE properly before being allowed to perform work requiring the use of PPE.
When the employer has reason to believe that any affected employee who has already been trained does not have the understanding and skill required by 29 CFR 1910.132, the employer shall retrain each such employee. Circumstances where retraining is required include, but are not limited to, situations where
- changes in the workplace render previous training obsolete
- changes in the types of PPE to be used render previous training obsolete
- inadequacies in an affected employee’s knowledge or use of assigned PPE indicate that the employee has not retained the requisite understanding or skill

The employer shall verify that each affected employee has received and understood the required training through a written certification that contains the name of each employee trained, the date(s) of training, and the subject of the certification.

h. Discuss the difficulties of optimizing PPE in a complex, multi-exposure environment.

The following is taken from Mike Kimberly’s *Personal Apparel Assessment (PAA) Cuts Operational Costs.*

Agencies can positively impact their bottom-line costs by conducting a personal apparel assessment (PAA), which focuses on seven key disciplines and 35 best practices to determine potential areas for cost improvement. These disciplines include cost performance, injury reduction, productivity improvements, standardization, training, and controls. The objective is to create a more consistent, compliant, and cost-effective PPE program.

The success of this type of program will depend on the agency’s ability to track the results on an ongoing basis. Financial models have been developed to quantify, measure, and document those results once the PAA has been completed and the recommendations implemented. This type of measurement will allow the agency to gauge the program’s success and verify true costs savings.

To conduct a thorough assessment, the agency should align itself with a partner that has the ability to provide the necessary resources, quantifiable documentation, and follow-up capabilities to ensure successful results. The measurement and improvement process should not end once the recommendations from the PAA are implemented. Follow-up to analyze any changes that occur within the organization and to ensure that new products and ideas are properly introduced is just as important as conducting the initial assessment.

Conducting a PAA goes beyond examining applications and providing product recommendations. It involves developing a complete understanding of the various job requirements, identifying critical issues, analyzing application processes and any variables that may exist, and reviewing operating procedures and the effect they may have on employees. Providing true solutions that will positively impact the workplace will be impossible without a thorough analysis of the entire process.

A successful assessment will require the support of key functions within the organization, including finance, operations, procurement, safety, and where applicable, union
representatives. In most cases, each of these departments has its own initiatives. The assessment will help each department determine which disciplines and their associated best practices represent the greatest opportunities for cost savings.

Measuring the cost performance of a agency’s PPE products is critical to controlling the company’s expenses. The objective is to identify optimum product solutions and implement best practices that will maximize performance. Employees must be asked for their input so the assessor can gain insight into the total process and how PPE products are used.

It will also be important to benchmark the agency’s present PPE product costs. This benchmark will allow the agency to use the financial models that will be put into place to measure the results of the recommendations that are implemented and to compare costs.

OSHA recently issued a report indicating that 70 percent of the workers that experienced hand injuries in manufacturing operations were not wearing gloves. Hand injuries among the remaining 30 percent occurred because hand protection was inadequate, damaged, or misapplied.

The objective of any PPE program is to provide solutions that significantly reduce recordable and non-recordable injuries and their associated costs. Wearing PPE is often a personal choice as far as employees are concerned. The OSHA study seems to indicate that many companies are not providing PPE products that are acceptable to employees and that provide the levels of protection needed for specific jobs. The direct (medical expenses) and indirect (lost time, decreased productivity) costs resulting from injuries can be enormous. Analyzing this discipline and implementing best practices provide agencies with an opportunity to reduce injuries and related costs.

i. Discuss the use and limitations of PPE in a heat stress environment.

The following is taken from Hazardous Waste Operations and Emergency Response Manual by Brian Gallant.

Heat stress is caused by a number of interacting factors, including environmental conditions, clothing, workload, and the individual characteristics of the worker. Because heat stress is probably one of the most common (and potentially serious) illnesses at hazardous waste sites, regular monitoring and other preventive precautions are vital.

Reduced work tolerance and the increased risk of excessive heat stress is influenced by the amount and type of PPE worn. PPE adds weight and bulk, severely reduces the body’s access to normal heat exchange mechanisms (evaporation, convection, and radiation), and increases energy expenditure. Therefore, when selecting PPE, each item’s benefit should be carefully evaluated in relation to its potential for increasing the risk of heat stress. Once PPE is selected, the safe duration of work/rest periods should be determined based on the

- anticipated work rate
- ambient temperature and other environmental factors
- type of protective ensemble
- individual worker’s characteristics and fitness
Because the incidence of heat stress depends on a variety of factors, all workers, even those not wearing protective equipment, should be observed carefully.

For workers wearing permeable clothing (e.g., standard cotton or synthetic work clothes), follow recommendations for monitoring requirements and suggested work/rest schedules in the current version of the ACGIH’s TLVs for heat stress. If the actual clothing worn differs from the ACGIH standard ensemble in insulation value and/or wind and vapor permeability, change the work/rest schedules accordingly.

For workers wearing semi-permeable or impermeable encapsulating ensembles, the ACGIH standard cannot be used. For these situations, workers should be evaluated when the temperature in the work area is above 70 °F (21 °C).

12. Industrial hygiene personnel shall demonstrate a working level knowledge of the design of engineering measures to control exposure.

   a. Discuss basic design principles for HVAC systems, including the following:
      - Local exhaust ventilation
      - Dilution ventilation
      - Air recirculation
      - Make-up air supply
      - Gloveboxes (design)
      - Exhaust cabinets (design and classification)

The local exhaust, dilution, and air recirculation information is taken from DOE-HDBK-1169-2003.

Local Exhaust Ventilation, Dilution Ventilation, and Air Recirculation
Regulations, technical guidance, and good practices emphasize the implementation of engineering controls to control exposure where feasible. Administrative controls are viewed less favorably, but are generally considered acceptable. Reliance on PPE, because of its reliance upon individual employee knowledge and other human variables, is regarded as the least desirable choice overall.

The most common form of engineering control is ventilation of the workplace. The industrial hygienist must be familiar with the components of the facility’s ventilation systems and the methods used to control both industrial sources of contaminants and indoor air contaminants. The industrial hygienist should also have a grasp of the state-of-the-art control technologies and methods used to evaluate control system performance.

Adequate ventilation is best achieved when the plant engineer, management, workers, and the industrial hygienist work together. Frequently, older facilities and their ventilation systems were designed for production purposes with little thought given to health considerations. Retrofit or redesign is sometimes required to meet today’s standards.

Local exhaust is most often the control technology of choice in that its components remove contaminants at their source. Dilution is sometimes used, but is less effective in that
contaminants remain (although they are less concentrated). Air recirculation may be used to conserve energy where air contaminants are of a low toxicity and concentration. Makeup air plays a key role in the HVAC process to introduce “fresh” air to the building and to replenish exhausted air. “Balanced” systems provide a good proportional flow of air to all areas, and also ensure that the HVAC system is at equilibrium between incoming and outgoing air. However, in some institutional or industrial situations, a “negative” or “positive” flow may be desirable to maintain parts of the building at positive or negative pressure.

Figure 17 from DOE-HDBK-1169-2003, *DOE Handbook: Nuclear Air Cleaning*, shows that the general approach to establish ventilation zones is in a three-tiered manner. Multizoned buildings are usually ventilated so that air flows from the less contaminated zone to the more contaminated zone. Areas from which air is not recirculated include areas that produce or emit dust particles, heat, odors, fumes, spray, gases, smoke, or other contaminants that cannot be sufficiently treated and could be potentially injurious to the health and safety of personnel or potentially damaging to equipment. These areas are 100 percent exhausted.

Recirculation within a zone (circularizing the air through a high-efficiency air cleaning system before discharge back to the zone) is permitted, but recirculation from a zone of higher contamination back to a zone of lesser contamination is prohibited. The interiors of exhaust and recirculating ductwork are considered to be of the same hazard classification as the zone they serve. Airflow must be sufficient to provide the necessary degree of contaminant dilution and cooling and to maintain sufficient pressure differentials between zones where there can be no backflow of air spaces of lower contamination, even under upset conditions. The pressure differentials should be determined during the facility’s design and should be in accordance with the applicable standards. Substantially higher differentials are often specified between primary and secondary confinement zones than for other boundaries.

Source: DOE-HDBK-1169-2003
The primary confinement zone comprises those areas where high levels of airborne contamination are anticipated during normal operations. Facility personnel do not normally enter primary confinement zones. When entry is necessary, it is done under tightly controlled conditions. This zone includes the interior of a hot cell, glovebox, piping, vessels, tanks, exhaust ductwork, primary confinement high-efficiency particulate air (HEPA) filter plenums, or other confinement for handling highly radiotoxic material. Confinement features must prevent the spread of radioactive material within the building under both normal operating and upset conditions up to and including the design basis accident for the facility. Complete isolation (physical separation) from neighboring facilities, laboratories, shop areas, and operating areas is necessary. Unavoidable breaches in the primary confinement barrier must be compensated for by an adequate inflow of air or safe collection of the spilled material. The exhaust system must be sized to ensure an adequate inflow of air in the event of a credible confinement breach. An air exhaust system that is independent of those serving surrounding areas is required. High-efficiency filters, preferably HEPA type, are typically required in air inlets, and two independently testable stages of HEPA filters are required in the exhaust. The exact number of testable stages is determined by safety analysis.

The secondary confinement zone comprises those areas where airborne contamination could be generated during normal operations or as a result of a breach of a primary confinement barrier. This zone consists of the walls, floors, ceilings, and associated ventilation systems that confine any potential release of hazardous materials from primary confinement. Related areas include glovebox operating areas, hot cell service or maintenance areas, and the ventilation system servicing the operating areas. Pressure differentials must be available to produce inward airflow into the primary confinement should a breach occur. Penetrations of the secondary confinement barrier typically require positive seals to prevent migration of contamination out of the secondary confinement zone. Air locks or a personnel clothing-change facility are recommended at the entrance to the zone. Restricted access areas are generally included in the secondary confinement zone.

The tertiary confinement zone comprises those areas where airborne contamination is not expected during normal facility operations. This zone consists of the walls, floors, ceilings, and associated exhaust system of the process facility. It is the final barrier against release of hazardous material to the environment. This level of confinement should never become contaminated under normal operating conditions. The secondary and tertiary boundaries may exist in common, as in a single-structure envelope.

**Makeup Air Supply**

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Makeup air is air that enters the workroom to replace air exhausted through the ventilation system. A room or plant with insufficient makeup air is said to be “air bound” or “air starved.” A ventilation system will not work properly if there is not enough air in the room to
Exhaust. This means that if the ambient static pressure within the room becomes slightly negative, the fan may not work properly against this additional resistance.

Makeup air should be supplied through a planned system rather than through random infiltration. The system should have the following features:

- The supply rate should exceed the exhaust rate by about 10 percent. This slight positive pressure in the building helps to keep out drafts and dust. The exception is a situation where no dust or airborne chemicals should travel from the workroom to adjacent offices or other areas. Then a slight negative pressure inside the workroom is preferred.
- The air should flow from cleaner areas of the plant through areas where contaminants may be present and finally to the exhaust system. Flow should also be from normal temperature areas to high-heat process areas. The makeup air supply system can be designed to provide some cooling in the summer in hot process areas.
- Makeup air should be introduced into the “occupied zone” of the plant, generally 8–10 feet from the floor. This gives the workers the benefit of breathing fresh air and, if the air is tempered (heated or cooled), maximizes the comfort provided by the makeup air.
- The air should be heated in winter to a temperature of 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.

Gloveboxes
The following is taken from DOE-HDBK-1169-2003.

Gloveboxes are enclosures that enable operators in various industries (e.g., nuclear, biological, pharmaceutical, microelectronics) to use their hands to manipulate hazardous materials through gloves without exposure to themselves or subsequent unfiltered release of the material to the environment. In the nuclear industry, gloveboxes provide primary confinement for radioactive material handling and process protection and are used to handle a diverse range of chemical, oxygen-sensitive, pyrophoric, hazardous, and nuclear materials. [Note: There are many other factors, (e.g., seismic, shielding, etc.) that could impact glovebox filtration design and operation. Secondary confinement may be provided by the room or building where the gloveboxes are located.]

Ventilation is the heart of the glovebox system. Nuclear materials requiring handling inside a glovebox usually present little or no penetrating radiation hazard, but emit radioactive particles that could be dangerous if inhaled. Gloveboxes prevent operators from inhaling radioactive particles as they work with various nuclear materials and help provide a clean, controlled, safe working environment. For glovebox ventilation to be effective, however, proper design pressures and flow criteria must be maintained. Glovebox pressures range from mostly negative (for confinement) to positive pressure environments (for process protection).

Failure to maintain correct operational pressures or to follow established operational procedures could render a glovebox both ineffective and unsafe.
**Exhaust Cabinets**

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. Some hoods are designed to fit around existing machinery while others are located next to the contaminant source. Even a plain duct opening is called a hood if that is where air enters the system. Different hoods work in different ways: some reach out and capture contaminants; others contain contaminants released inside the hood and prevent them from escaping into the workroom. Some hood designs feature a long, narrow slot to distribute the air flow along the length of an open surface tank, welding bench, or laboratory hood.

- **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 system and through the ducts and other components. It functions by inducing a negative pressure or suction in the ducts leading to the hoods and positive pressure in the system after the fan. The fan converts electrical power into pressure and increased air velocity.

- **Air cleaner**—a device to remove airborne material that may be needed before the exhaust air is discharged into the community environment. Air cleaners to remove solid and gaseous contaminants are available.

**b. Describe the design principles and performance of air filtration systems, and explain the roles they play in minimizing worker exposure to chemical and biological hazards.**

- **High efficiency particulate air (HEPA) filtration (filter testing and certification, design features)**

The following is taken from DOE-HDBK-1169-2003.

Air cleaners are typically categorized as one of two types. The first type is used to remove industrial type pollutants—dusts, mists, fumes, vapors, and biologicals—from the immediate and surrounding areas. Devices such as precipitators, centrifuges, scrubbers, fabric, and HEPA filters are commonly used in these applications. The second type of air cleaner is used in recirculating HVAC systems as in-line devices to reduce low-level or toxic contaminants. These include fiber filters or electrostatic precipitators.

DOE-HDBK-1169-2003, *DOE Handbook: Nuclear Air Cleaning*, states that the complexity of the air cleaning system needed to provide satisfactory working conditions for personnel and to prevent the release of radioactive or toxic substances to the atmosphere depends on the following factors:

- The nature of the contaminants to be removed (e.g., radioactivity, toxicity, corrosivity, particle size and size distribution, particle shape, and viscidity)
- Heat (e.g., process heat, fire)
- Moisture (e.g., sensible humidity process vapors, water introduced from testing)
- Radiation (e.g., personnel exposure and material suitability considerations)
- Other environmental conditions to be controlled
- Upset or accident, or accident hazard considerations
In designing an air cleaning system, development of the environmental operating conditions must be the first step. Before appropriate individual system components can be environmentally qualified, the designer must consider all environmental parameters on an integrated basis.

The types of contaminants in the gas stream must be identified. All of the contaminants, both particulate and gaseous, including concentration levels and particle sizes, must be evaluated to properly design and size the system. The presence of other particulates, gases, and chemicals must be clearly determined. The presence of volatile organic chemicals, entrained water, and acids will affect the performance of various system components and must be addressed, if they are present, in the design of the system and its components.

Pressure is one of a number of variables that needs to be evaluated in the course of designing the air cleaning system because it can significantly affect the fan power requirements and the airflow rate. The pressure of the airstream can be impacted significantly by the change from the normal operating pressure to the accident or upset air pressure.

Moisture is an important consideration in air cleaning system design. Moisture in the air may affect the performance of the air cleaning system by binding the particulate filters and/or blocking pores and fissures in the activated charcoal.

Although some air cleaning system components are prequalified to operate in a given temperature range, the air cleaning system designer must verify all components of the system will function at the maximum and minimum temperature conditions for the specified application. If the temperature range of the specific application exceeds the components’ design qualification temperature, requalification is necessary to meet the operational and design life requirements of the system.

Many radiochemical operations generate acid or caustic fumes that can damage or destroy filters, system components, and construction materials. Some products of radiochemical operations can produce shock sensitive salts (e.g., perchloric acid salts and ammonium nitrate) that must be specifically considered in the design and operation. The air cleaning system designer must select components and materials of construction suitable for the corrosive environment to ensure high levels of system performance and reliability.

Vibration and pulsation can be produced in an air or gas cleaning installation by turbulence generated in poorly designed ducts, transitions, dampers, and fan inlets, and by improperly installed or balanced fans and motors. Excessive vibration or pulsation can result in eventual mechanical damage to system components when accelerative forces (e.g., from an earthquake or tornado) coincide with the resonant frequencies of those components. Important factors in the prevention of excessive vibration and noise include planning at the initial building layout stage and space allocation to ensure that adequate space is provided for good aerodynamic design of ductwork and fan connections.

Emergency electrical power is required when specified by facility safety documentation. Emergency power has specific requirements and may not be required for all systems. Standby electrical power is used for many safety air cleaning systems not classified as safety class. Standby power is required for safety-significant air cleaning systems. The amount of
emergency power required for fans, dampers, valves, controls, and electrical heaters to control the relative humidity of the effluent airstream (as dictated by the facility design requirements) must be accounted for during accident or upset conditions. Close coordination between the system designers of both the air cleaning and electrical systems is required to ensure this is done as there is a set amount of emergency power available.

Workroom ventilation rates are based primarily on cooling requirements, the potential combustion hazard, and the potential inhalation hazard of substances that are present in or could be released to the workroom.

Concentrations of radioactive gases and aerosols in the air of occupied and occasionally occupied areas should not exceed the derived air concentrations established for occupationally exposed persons under normal or abnormal operating conditions, and releases to the atmosphere must not exceed permissible limits for nonoccupationally exposed persons. Because radioactive gases and aerosols might be released accidentally in the event of an equipment failure, a spill, or a system upset, the ventilation and air cleaning facilities must be designed to maintain airborne radioactive material within prescribed limits during normal operations. In addition, the ventilation and air cleaning facilities must perform in accordance with expectations established during the evaluation of potential accident conditions.

HEPA Filters

The following is taken from DOE-STD-3020-2005.

As directed by the Secretary of Energy’s June 4, 2001 memorandum, 100 percent Quality Assurance Testing of HEPA Filters at the DOE Filter Test Facility (FTF), prior to use in DOE facilities, filters meeting the following criteria shall be delivered to the FTF for additional quality assurance testing.

- HEPA filters that are used in confinement ventilation systems in category 1 and category 2 nuclear facilities that perform a safety function in accident situations, or are designated as important to safety (i.e., safety class or safety significant per DOE-STD-3009-94).
- HEPA filters necessary for habitability systems (e.g., filters that protect workers who must not evacuate in emergency situations because of the necessity to shutdown or control the situation).
- For all other applications where HEPA filters are used in confinement ventilation systems for radioactive airborne particulates, develop and document an independent, tailored filter QA testing program that achieves a high degree of fitness for service. The program should include the testing of a sample of filters at the FTF. The size of the sample to be tested should be large enough to provide sufficient statistical power and significance to assure the required level of performance.

HEPA filters shall be qualified per ASME AG-1 and section 6.1 of DOE-STD-3020-2005. The filter media shall comply with ASME AG-1.

All HEPA filters shall be tested by the manufacturer and in addition, those identified in the previous paragraph shall be tested by the FTF to the following criteria:
- Penetration at 100% of manufacturer rated airflow.
- Penetration at 20% of manufacturer rated airflow for filters rated at 125 actual cubic feet per minute (ACFM) and greater.

Mandatory performance requirements for HEPA filters are set out below. These performance requirements shall be demonstrated by test and inspection by the manufacturer. These performance requirements shall also be demonstrated by test and inspection by the FTF when applicable.
- Penetration: Aerosol penetration for any HEPA filter shall not exceed 0.03% (0.0003) at 0.3 micrometer particle size.
- Resistance: Airflow resistance across the HEPA filter shall conform to the limits listed in tables 5.1, 5.3, 5.4, and 5.5 in DOE-STD-3020-2005.

Tests for resistance to airflow shall be conducted at flow rates expressed in ACFM.

Construction materials for HEPA filters shall be selected to avoid generation of EPA-regulated wastes as specified in 40 CFR 261, “Identification and Listing of Hazardous Waste”. For this reason, cadmium is no longer acceptable for treatment of filter cases, nor is asbestos acceptable as a HEPA filter component. State and local regulations may contain additional restrictions.

c. **Discuss the interpretation and applicability of regulations and standards governing ventilation systems, such as the following:**
   - DOE-HDBK-1169-2003, Nuclear Air Cleaning Handbook

Legal requirements for ventilation systems are addressed in 29 CFR 1910.94. However, these requirements are antiquated and limited to a few industrial situations, and are not generally useful.

Recognized consensus standards play a key role in ventilation practices. Standards published by ANSI, ASHRAE, the AIHA, and ACGIH are at the forefront of these documents. Of significance in the control of indoor air quality is ANSI/ASHRAE 62.1-2007, *Ventilation for Acceptable Air Quality.*

DOE-HDBK-1169-2003, *DOE Handbook: Nuclear Air Cleaning*, chapter 2, “System Considerations,” identifies numerous regulations and standards applicable to ventilation systems. For example, the design of workroom ventilation systems should be consistent with the requirements of 10 CFR 835, “Occupational Radiation Protection,” subpart K, “Design and Control,” which establishes DOE’s design objectives for workplace radiological control. Furthermore, effluent releases from ventilation systems must be in accordance with DOE directives and relevant regulatory requirements (e.g., DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, and 40 CFR 61, subpart H, “National Emission Standards for Air Pollution”).
Also, for interpretations of 10 CFR 851 and technical safety issues, DOE established the DOE Response Line at 1-800-292-8061. The DOE OSH Standards Interpretations Response Line clarifies the requirements contained in the OSH standards to promote consistent application of those standards throughout DOE. The toll-free line, an extension of the DOE Interpretations Guide to OSH Standards, provides timely processing of DOE and DOE contractor requests for clarification of OSH standards. The 800-line is staffed by OSH experienced personnel who have access to a database that contains a wealth of information on OSH standards. The information database used by the 800-line staff is continually updated. In addition, new interpretations are included in the quarterly updates, which are sent to registered users of the DOE Interpretations Guide to OSH Standards.

d. Describe the following environmental factors:
   - Atmospheric dispersion modeling
   - Control of hypo- and hyperbaric conditions
   - Psychrometry

*Atmospheric Dispersion Modeling*

The following is taken from the U.S. EPA, *Technology Transfer Network Support Center for Regulatory Atmospheric Modeling*.

Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to predict concentrations at selected downwind receptor locations. These air quality models are used to determine compliance with National Ambient Air Quality Standards and other regulatory requirements such as New Source Review and Prevention of Significant Deterioration regulations. These models are addressed in Appendix A of EPA’s *Guideline on Air Quality Models* (also published as Appendix W of 40 CFR 51), which was originally published in April 1978 to provide consistency and equity in the use of modeling within the U.S. air quality management system. These guidelines are periodically revised to ensure that new model developments or expanded regulatory requirements are incorporated.

*Control of Hypo- and Hyperbaric Conditions*

According to the National Safety Council, *Fundamentals of Industrial Hygiene*, hypo- and hyperbaric environments are sometimes advantageous for biomedical, biophysical, and physical chemistry research and therapy. The use of pressurized or depressurized chambers presents unusual conditions and challenges for the industrial hygienist, including issues related to gas solubility, vapor pressures, and density properties, which may increase the dose to employees, affect engineering controls, and influence sampling results.

*Psychrometry*

e. Discuss the principles of isolation and enclosure as they relate to the following:
   - Noise
   - Air contaminants
   - Radiation

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

*Noise, Air Contaminants, and Radiation*

Potentially hazardous operations should be isolated to minimize exposure to employees. The isolation can be a physical barrier, such as acoustic panels used to minimize noise transmission from a whining blower or a screaming ripsaw.

The isolation can be in terms of time, such as providing remote control semiautomatic equipment so that an operator does not have to stay near the noisy machine constantly. Or the worker may be isolated or enclosed in a soundproof control booth with a clean source of air supplied to the booth.

Isolation is particularly useful for jobs requiring relatively few workers and when control by other methods is difficult or not feasible. The hazardous job can be isolated from the rest of the work operations, thus eliminating exposure for the majority of workers. Additionally, the workers actually at workstations where contaminants are released should be protected by installing ventilation systems, which probably would not be satisfactory if the workstation were not isolated.

Exposure to employees may likewise be minimized by isolating hazardous material in place. Exposure to asbestos-containing materials and lead-based paint can be abated in some instances by sealing these materials in airtight enclosures.

Isolation can also be provided by appropriate use of distance and time, for example, with respect to radiation and noise exposure. Both radiation and noise exposures decrease with an increase in the distance from the source and a decrease in the exposure time.

f. Discuss the economic feasibility parameters of the following:
   - Engineering controls, including process change, substitution for less toxic material, and pollution prevention principles (including environmentally referable purchasing)
   - Administrative controls
   - PPE

The following is taken from NIOSH, *Engineering Controls, Input: Economic Factors*.

Market forces, structural changes, and emerging threats may affect levels of resources available for occupational safety and health initiatives within the engineering control emphasis area.

Control methods at the top of the control hierarchy (engineering controls, administrative controls, PPE) are potentially more effective and protective than those at the bottom.
Following this hierarchy normally leads to the implementation of inherently safer systems, where the risk of illness or injury has been substantially reduced.

Short-term cost for implementing controls typically follows the order of the hierarchy, with elimination and substitution being sometimes impossible or cost prohibitive in an existing situation. Elimination and substitution of hazards may be inexpensive and simple to implement if the process is at the design or development stage. Eliminating the presence of a hazardous substance or condition in the workplace obviously prevents illness and injury from that substance or condition. The substitution of a less hazardous substance or condition, likewise, reduces resulting illness or injury. Some economic factors that must be considered include the quality of the product, cost of substitute materials, return on investment, and speed and ease of production.

Long-term expenditures, on the other hand, tend to follow the hierarchy in reverse order, with the use of personal protective equipment and the implementation of administrative controls incurring mounting expense with time. While not insignificant, the expense for developing and implementing these lower level controls typically is not as much as for the design and construction of an engineering control solution. Over time, however, the maintenance and operation of an engineering control is overtaken by the continued cost of supplies, medical monitoring, training, and other operational costs involved with administrative controls and personal protective equipment.

g. Discuss how engineering controls may be implemented for each of the following:

- Nonionizing radiation
- Ionizing radiation
- Noise
- Vibration
- Repetitive motions
- Lifting heavy objects
- Biological hazards
- Heat and humidity
- Cold stress

The following descriptions are taken from the National Safety Council, *Fundamentals of Industrial Hygiene*, unless stated otherwise.

*Nonionizing Radiation*

A common approach used as engineering controls for nonionizing radiation is shielding. Shields that are used to control nonionizing radiation are different from other forms of shielding that work by stopping an agent with a barrier. Magnetic fields (nonionizing radiation) are controlled using permeable alloy that confines the magnetic flux lines and diverts them. Magnetic fields exist as circuits; they do not reach out into space as electric field lines and ionizing radiation do. Magnetic shielding can be made using high-nickel alloys called mu metal or soft iron. Forming mu metal into complex shapes is expensive, and mu metal is easily damaged. Magnetic field shielding alloys are less permeable at low field strengths than at high field strengths, so they work best at high field strengths. Such shielding is best applied near the field source, whenever practical. Another
approach is to use nonpermeable metals such as copper or aluminum to produce eddy currents that cancel out the original magnetic field.

_**Ionizing Radiation**_

Shielding is commonly used to protect against radiation from radioactive sources. The more mass that is placed between a source and a person, the less radiation the person will receive. For a high-density material such as lead, the barrier thickness required for a given attenuation or $x$- or gamma-radiation is less than it is for a less dense material such as concrete.

Shielding can take many forms. These include cladding on radioactive material, containers with heavy walls and covers for radioactive sources, cells with thick, high-density-concrete walls that have viewing windows filled with high-density transparent liquid for remote handling of high-level gamma-emitters, and a deep layer of water for shielding against gamma-radiation from spent nuclear reactor fuel. Shielding calculations are often highly technical and require the services of an expert in this area.

_**Noise and Vibration**_

When starting a noise-reduction program, it is most desirable to apply engineering principles that are designed to reduce noise levels. The application of known noise-control principles can usually reduce any noise to any desired degree. However, economical considerations or operational necessities can make some applications impractical.

The following are examples of engineering principles that can be applied to reduce noise levels:

- **Maintenance**
  - Replacement or adjustment of worn, loose, or unbalanced parts of machines
  - Lubrication of machine parts and use of cutting oils
  - Use of properly shaped and sharpened cutting tools

- **Substitution of machines**
  - Larger, slower machines for smaller, faster ones
  - Step dies for single operation dies
  - Presses for hammers
  - Rotating shears for square shears
  - Hydraulic presses for mechanical presses
  - Belt drives for gears

- **Reduction of the sound radiation from vibrating surfaces**
  - Reduction of the radiating area
  - Reduction of the overall size
  - Perforation of the surfaces

_**Repetitive Motions**_

Engineering controls such as work station redesign, adjustable fixtures, or tool redesign are methods to reduce repetitive motion injuries.
Lifting Heavy Objects
Refer to competency 5.b, “Requirements of Material Handling,” for a discussion of seven keys of load handling.

Biological Hazards
Biological hazards may be controlled either by initial design specifications or by methods of substitution, isolation, enclosure, or ventilation.

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

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

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

Heat and Humidity
The following is taken from NIOSH 86-112.

Many industries have attempted to reduce the hazards of heat stress by introducing engineering controls, training workers in the recognition and prevention of heat stress, and implementing work-rest cycles. Heat stress depends, in part, on the amount of heat the worker's body produces while a job is being performed. The amount of heat produced during hard, steady work is much higher than that produced during intermittent or light work. Therefore, one way of reducing the potential for heat stress is to make the job easier or lessen its duration by providing adequate rest time. Mechanization of work procedures can often make it possible to isolate workers from the heat sources (perhaps in an air-conditioned booth) and increase overall productivity by decreasing the time needed for rest. Another approach to reducing the level of heat stress is the use of engineering controls which include ventilation and heat shielding.

Number and Duration of Exposures
Rather than be exposed to heat for extended periods of time during the course of a job, workers should, wherever possible, be permitted to distribute the workload evenly over the day and incorporate work-rest cycles. Work-rest cycles give the body an opportunity to get rid of excess heat, slow down the production of internal body heat, and provide greater blood flow to the skin.
Workers employed outdoors are especially subject to weather changes. A hot spell or a rise in humidity can create overly stressful conditions. The following practices can help to reduce heat stress:

Postponement of Nonessential Tasks,
Permit only those workers acclimatized to heat to perform the more strenuous tasks, or

Provide additional workers to perform the tasks keeping in mind that all workers should have the physical capacity to perform the task and that they should be accustomed to the heat.

Thermal Conditions in the Workplace
A variety of engineering controls can be introduced to minimize exposure to heat. For instance, improving the insulation on a furnace wall can reduce its surface temperature and the temperature of the area around it. In a laundry room, exhaust hoods installed over those sources releasing moisture will lower the humidity in the work area. In general the simplest and least expensive methods of reducing heat and humidity can be accomplished by:
- Opening windows in hot work areas,
- Using fans, or
- Using other methods of creating airflow such as exhaust ventilation or air blowers.

Rest Areas
Providing cool rest areas in hot work environments considerably reduces the stress of working in those environments. There is no conclusive information available on the ideal temperature for a rest area. However, a rest area with a temperature near 76°F appears to be adequate and may even feel chilly to a hot, sweating worker, until acclimated to the cooler environment. The rest area should be as close to the workplace as possible. Individual work periods should not be lengthened in favor of prolonged rest periods. Shorter but frequent work-rest cycles are the greatest benefit to the worker.

Drinking Water
In the course of a day's work in the heat, a worker may produce as much as 2 to 3 gallons of sweat. Because so many heat disorders involve excessive dehydration of the body, it is essential that water intake during the workday be about equal to the amount of sweat produced. Most workers exposed to hot conditions drink less fluids than needed because of an insufficient thirst drive. A worker, therefore, should not depend on thirst to signal when and how much to drink. Instead, the worker should drink 5 to 7 ounces of fluids every 15 to 20 minutes to replenish the necessary fluids in the body. There is no optimum temperature of drinking water, but most people tend not to drink warm or very cold fluids as readily as they will cool ones. Whatever the temperature of the water, it must be palatable and readily available to the worker. Individual drinking cups should be provided—never use a common drinking cup.

Heat acclimatized workers lose much less salt in their sweat than do workers who are not adjusted to the heat. The average American diet contains sufficient salt for acclimatized workers even when sweat production is high. If, for some reason, salt replacement is
required, the best way to compensate for the loss is to add a little extra salt to the food. Salt tablets should not be used.

**Cold Stress**

Engineering controls attempt to reduce heat loss from the person as a whole or from exposed skin. Control includes increasing air temperature and decreasing air speed in the work zone, and providing rewarming areas. Specifically engineering controls include the following:

- General or spot heating, including hand warming
- Hand warming for fine hand work below 16 °C
- Minimized air movement
- Reduced conductive heat transfer
- Redesigned equipment or process to control systemic and local cold stress
- Warming shelters in exposures below -7 °C

13. Industrial hygiene personnel shall demonstrate a working level knowledge of the design of administrative measures to control exposure or protect employees.

a. Describe how the following administrative measures may contribute to exposure control:

- Substitute hazardous materials
- Identify opportunities to reduce use of toxic materials during design reviews
- Change work practices
- Change operations and scheduling
- Institute standard operating procedures
- Reduce exposure time
- Establish work/rest regimen for heat stress control
- Encourage good personal hygiene practices
- Promote and implement good housekeeping practices

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

**Substitute Hazardous Materials; Identify Opportunities to Reduce Use of Toxic Materials during Design Reviews**

An often effective industrial hygiene method of control is the substitution of nontoxic or less toxic materials for highly toxic ones. However, an industrial hygienist must exercise extreme caution when substituting one chemical for another to ensure that some previously unforeseen hazard does not occur along with the substitution.

A change in the physical condition of raw materials received by a facility for further processing may eliminate health hazards. Pelletized or briquette forms of material can drastically reduce atmospheric dust contamination in some processes.

There are instances when substitution of some toxic materials may be impossible or impractical, as in the manufacture of pesticides, drugs, or solvents, and in processes producing ionizing radiation.
Substituting less hazardous materials or process equipment may be the least expensive and most positive method of controlling many occupation health hazards and can often result in substantial savings. Exposure control by substitution is becoming more important from an environmental health and community air pollution perspective as well. Process materials should be selected only after review of their smog production and ozone depletion characteristics.

Change Work Practices
A change in process offers an ideal chance to concomitantly improve working conditions. Most changes are made to improve quality or reduce the cost of production. However, in some cases, a process can be modified to reduce the dispersion of dust or fumes and thus markedly reduce the hazard. For example, in the automotive industry, the amount of lead dust created by grinding solder seams with small, high-speed rotary sanding disks was greatly reduced by changing to low-speed, oscillating-type sanders. More recently, lead solder was replaced with tin solder and silicone materials.

Change Operations and Scheduling; Institute Standard Operating Procedures; Reduce Exposure Time; Establish Work/Rest Regimen for Heat Stress Control
Reduction of work periods is another method of control in limited areas where engineering control methods at the source are not practical. Heat stress can be managed by following a work-rest regimen that prevents excessive fatigue and reduces heart rate. For example, in the job forge, foundry, and construction industries, especially in hot weather, frequent rest periods are used to minimize the effects of exposure to high temperatures, thereby lessening the danger of heat exhaustion or heatstroke.

For workers who must labor in a compressed-air environment, schedules of maximum length of work shift and length of decompression time have been prepared. The higher the pressure, the shorter the work shift and the longer the decompression time period.

However, job rotation, when used as a way to reduce employee exposure to toxic chemicals or harmful physical agents, must be used with care. Rotation, although it may keep exposure below recommended limits, exposes more workers to the hazard.

Encourage Good Personal Hygiene Practices
Personal hygiene is an important control measure. The worker should be able to wash exposed skin promptly to remove accidental splashes of toxic or irritant materials. If workers are to minimize contact with harmful chemical agents, they must have easy access to hand-washing facilities.

Inconveniently located washbasins invite such undesirable practices as washing at workstations with solvents, mineral oils, or industrial detergents, none of which is appropriate or intended for skin cleansing.

Many workplace hand cleansers are available as plain soap powders, abrasive soap powders, abrasive soap cakes, liquids, cream soaps, and waterless hand cleaners.
Powdered soaps provide a feeling of removing soils because of stimulation of the nerve endings in the skin by the abrasives. Waterless cleaners have become very popular because they remove most soils, such as greases, grimes, tars, and paint, with relative ease. Be aware, however, that some waterless hand cleaners have solvent bases. Soaps may also contribute to industrial dermatitis. Sensitive persons may require pH-neutral soaps or moisturizing agents. Antibacterial soaps are necessary in workplaces where infectious agents may be present.

Promote and Implement Good Housekeeping Practices

Good housekeeping plays a key role in the control of occupational health hazards. Good housekeeping is always important, but where there are toxic materials, it is of paramount importance, and often mandated by OSHA regulation.

Immediate cleanup of any spills of toxic materials is a very important control measure. A regular cleanup schedule using vacuum cleaners is an effective method of removing dirt and dust from the work area. Never use compressed air to remove dust from rafters and ledges.

Good housekeeping is essential where solvents are stored, handled, and used. Immediately remedy leaking containers or spigots by transferring the solvent to sound containers or by repairing the spigots. Clean up spills promptly. Deposit all solvent-soaked rags or absorbents in airtight metal receptacles and remove daily to a safe location for proper disposal.

b. Discuss how the following may be needed to implement effective exposure control:

- Medical surveillance of exposed employees
- Medical removal protection for affected workers
- Pre-placement exams and periodic medical screening

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Medical Surveillance of Exposed Employees; Pre-placement Exams and Periodic Medical Screening

Health surveillance, although not an occupational exposure control, can be used to prevent health impairments by means of periodic evaluations. A health surveillance program includes pre-placement, periodic, special purpose, and hazard-oriented examinations.

Medical surveillance is mandated by specific OSHA, Mine Safety and Health Administration (MSHA), and EPA regulations. Over 30 OSHA standards and proposed standards contain medical surveillance requirements. Among these are the asbestos, lead, formaldehyde, and hazardous waste operation standards.

Hazard-oriented medical surveillance monitors biological indicators of absorption of chemical agents based on analysis of the agent or its metabolite in blood, urine, or expired air. Inorganic lead absorption is measured by blood lead levels, and carbon monoxide absorption is indicated by carboxyhemoglobin levels in blood or carbon monoxide in exhaled air.
Medical Removal Protection for Affected Workers
The following is taken from DOE G 440.1-7A.

Title 10 CFR 850.35 establishes the medical removal protection (MRP) and MRP benefit provisions of the rule. It addresses the medical basis for MRP, temporary and permanent removal, worker consultation, return to work, and MRP benefits. Medical surveillance can be effective in protecting workers’ health only when workers voluntarily seek medical attention when they feel ill, refrain from efforts to conceal their true health status, and fully cooperate with examining physicians.

Without MRP, employers would be free to maintain workers diagnosed with sensitivity or disease in their current jobs, which would not sufficiently protect worker health. Alternatively, employers could choose to terminate workers or transfer them from higher-paying, beryllium-exposed jobs to lower paying, non-beryllium jobs. This might be protective, but it would impair the worker’s standard of living. In either case, the effectiveness and integrity of the medical surveillance program would be compromised.

With MRP, workers are assured of being removed to jobs without exposure if removal is determined to be necessary to protect their health. With MRP benefits, workers are assured that their normal earnings and job status will be protected for a sufficient period of time if the results of the program require removal from their exposed jobs, and if they participate in the medical surveillance program established by the employer as a condition for receiving MRP benefits. This interval allows time for retraining and placement in other jobs.

Title 10 CFR 850.35(a) requires employers to offer workers medical removal from exposure on each occasion that the site occupational medical director (SOMD) determines in a written medical opinion that it is medically appropriate to do so. The SOMD’s determination must be based on
- one or more positive lymphocyte proliferation test results,
- a diagnosis of disease,
- an examining physician’s recommendation, or
- any other signs or symptoms that the SOMD deems medically sufficient.

Medical removal can be temporary or permanent. Title 10 CFR 850.35(a)(1) requires employers to offer temporary removal pending a final medical determination of the worker’s health. Final determination is dependent on the outcome of the multiple physician review process or the alternate medical determination process.

Employers are required to transfer workers who accept temporary removal to comparable jobs for which they are qualified (or for which they can be trained in a short time) and where exposures are as low as possible.

Pre-placement Exams and Periodic Medical Screening
The following is taken from the OSHA Technical Manual.

Sound medical practice dictates that employees who will be working with potential exposure in the workplace have an initial evaluation consisting of a history, physical exam, and
laboratory studies. Information made available by the employer to the examining physician should be

- a description of the employee’s duties as they relate to the employee’s exposure;
- the employee’s exposure levels or anticipated exposure levels;
- a description of any personal protective equipment used or to be used;
- information from previous medical examinations of the employee, which is not readily available to the examining physician.

The history details the individual’s medical and reproductive experience with emphasis on potential risk factors, such as past hematopoietic, malignant, or hepatic disorders. It also includes a complete occupational history with information on extent of past exposures (including environmental sampling data, if possible) and use of protective equipment.

The physical examination should be complete, but the skin, mucous membranes, cardiopulmonary and lymphatic systems, and liver should be emphasized. An evaluation for respirator use must be performed in accordance with 29 CFR 1910.134, if the employee will wear a respirator. The laboratory assessment may include a complete blood count with differential, liver function tests, blood urea nitrogen, creatinine, and a urine dipstick. Other aspects of the physical and laboratory evaluation should be guided by known toxicities of the exposure. Due to poor reproducibility, interindividual variability, and lack of prognostic value regarding disease development, no biological monitoring tests (e.g., genotoxic markers) are currently recommended for routine use in employee surveillance. Biological marker testing should be performed only within the context of a research protocol.

The following is taken from OSHA, Medical Screening.

Medical screening is a method for detecting disease or body dysfunction before an individual would normally seek medical care. Screening tests are usually administered to individuals without current symptoms, but who may be at high risk for certain adverse health outcomes.

14. Industrial hygiene personnel shall demonstrate a working level knowledge of the methods used to promote effective communication and control of hazards.

a. Describe how to prepare a technical report.

The following is taken from ANSI/NISO Z39.18-1995.

A technical report contains three major sections: front matter, text (also called body), and back matter. Each section contains individual elements that vary according to the subject matter and length of the report. Each major division is part of a whole and is consistent with the other major divisions in style and appearance.

**Front Matter**

Front matter consists of all materials preceding the text and serves several purposes: to give the reader a general idea of the purpose and scope of the report; to provide background about or a context for the report; and to list where in the report the reader can find specific chapters,
headings, figures, and tables. It also provides information that is needed for cataloging the report for bibliographic databases.

**Text**
The text is the part of the report in which the author describes methods, assumptions, and procedures; presents and discusses the results; and draws conclusions and recommends actions based on those results.

The organization of a report depends on its subject matter and audience as well as on its purpose. Thus, the organization of the text may vary widely from report to report. Information on the content of text elements follows.

**Summary**
A summary is a required element of the text of a report. It clearly states the key points of the report, including the problem under investigation, the principal results and conclusions, and recommends a course of action for decision makers. Because the summary restates key points, material not included in the text does not appear in the summary.

Introductory material (purpose, scope, limitations), descriptive material (nature and method of investigation), and the most important results and conclusions are summarized with emphasis on the findings of the research and recommendations. The length of the summary typically does not exceed 2 percent of the body of the report.

Although a summary depends on the text in that it introduces no new information, it is independent of the text from the reader’s point of view; therefore, all symbols, abbreviations, and acronyms are defined and unusual terms are explained.

A summary does not contain references. If a report exceeds 50 pages in length, a separate executive summary is often prepared for a management-level audience. An executive summary is a nontechnical presentation that provides an adequate level of detail for decision makers who need a basic understanding of a research problem and the major findings but who do not plan to read the report in its entirety.

**Introduction**
The required introduction provides readers with general information that they need to understand more detailed information in the rest of the report. It introduces the subject, the purpose, the scope, and the way the author plans to develop the topic. The introduction also indicates the audience for the report: who is expected to read it and act on its recommendations or review its findings. The introduction does not, however, include findings, conclusions, or recommendations.

The statement of the subject defines the topic and associated terminology and may include the theory behind the subject, its historical background, and its significance. The statement of the purpose indicates the reason for the investigation; the statement of the scope indicates the extent and limits of the investigation. The author’s plan for developing the report usually presents a narrative outline of the text.
Methods, Assumptions, and Procedures
The methods, assumptions, and procedures used in an investigation are succinctly described so that readers can evaluate the results without referring extensively to the references. The description is complete enough that a knowledgeable reader could duplicate the procedures of the investigation. The system of measurement (for example, metric or English) is identified. If the research included apparatus, instruments, or reagents, a description of the apparatus, the design and precision of the instruments, and the nature of the reagents are explained in this required section of text.

Results and Discussion
A required element of the report text, results and their discussion are presented in the same or in separate sections. The discussion section indicates the degree of accuracy and the significance of the results of the research described in a report. Specific values used to substantiate conclusions appear in the text. Supporting details not essential to an understanding of the results appear in an appendix. Sometimes a section such as Presentation of Results, includes figures and tables and their captions (titles). Such figures and tables appear as close as possible following their discussion in the text.

Conclusions
The required conclusion section interprets findings that have been substantiated in the discussion of results and discusses their implications. The section introduces no new material other than remarks based on these findings. It includes the author’s opinions. The conclusion section is written so that it can be read independently of the text.

Recommendations
The optional recommendations section presents a course of action based on the results of the study. Types of studies for which recommendations are often made include tests and experiments, field trials, specific design problems, feasibility studies, and market appraisals. Recommendations might include additional areas for study, alternate design approaches, or production decisions. Specific recommendations are presented in a numbered or bulleted list that is introduced by an informative, lead-in sentence.

References
The references section appears as the last section of the text and begins on a new page. This section may also be called “Sources” or “Works Cited,” depending on the nature of the referenced materials. To help readers use and assess referenced materials, all references include the following elements: name of author(s), title of referenced work, and publication data. If a government document is referenced, the National Technical Information Service number is included in the reference to facilitate user access to the government document.

Back Matter
The back matter supplements and clarifies the body of the report (for example, appendixes), makes the text easier to use (for example, glossary; lists of symbols, abbreviations, and
b. Discuss major record-keeping requirements.

The following is taken from DOE-STD-6005-2001.

DOE and contractor line management must ensure written hazard assessment and control records are developed and maintained for all potentially hazardous work operations and activities. This includes assessments where no significant worker exposures are expected or determined. This latter case is important since new exposure effects may be identified and retrospective health concerns can only be addressed by documented assessment records. Consequently, assessments for operations determined to have no significant exposure potential (i.e., negative exposure) should be appropriately documented for historical purposes following the standard protocol for all surveys. Because of the significance of the information contained in these records, it is crucial that the persons assigned this task be appropriately trained. Critical records should be reviewed and approved by the senior industrial hygienist or designee. All such record keeping must comply with the requirements of 29 CFR 1910.1020, any applicable DOE directives, and/or applicable OSHA hazard-specific or expanded health standards, as well as any applicable requirements imposed by the Americans with Disabilities Act, the Privacy Act of 1974, the Freedom of Information Act, or any other applicable law.

c. Discuss how to ensure the implementation of preferred control measures (including the desired hierarchy of controls), alternatives, and/or interim control measures.

The following is taken from DOE-STD-6005-2001.

An efficient means of communicating requirements for workplace controls, and one that is increasingly used for projects and remediation, is the completion of standardized work permits. The advantage of permits is that they have little or no narrative, but instead contain spaces or blocks for each category of action that may be required, e.g., PPE, engineering controls, training, and medical certification. They are quickly and easily understood, and are available in the workplace where they are needed. They also provide very fine control over the workplace because they can be revised for each phase of a project, as opposed to relying upon a necessarily more general annual survey of an affected department or work center. The principal drawback to a permitting system is that all of its documentary support is elsewhere and must be accessed separately. This separation of information poses a challenge to auditors and the future defensibility of decisions unless permitting recommendations are regularly collated and audited with respect to program goals and compliance.

DOE and OSHA require that control measures be prioritized in accordance with the following hierarchy of controls.
Engineering Controls
The following are engineering controls that limit worker exposures:
- Change to a less hazardous process or substitute a less hazardous material or piece of equipment.
- Isolate or enclose the process or operation to prevent worker exposure to hazardous agents.
- Use mechanical ventilation or other engineered controls to prevent or reduce worker exposure to hazardous agents.

Work Practice and Administrative Controls
Although administrative controls can minimize worker exposures, they are often unreliable and difficult to implement. For this reason, engineering controls are preferable to administrative and work practice controls. However, the following are work practice and administrative controls that limit worker exposures:
- Develop work practices and procedures (e.g., standard operating procedures, limited access, and showering and changing of clothes) to reduce/minimize hazardous exposures.
- Maintain administrative controls (e.g., schedule hazardous activities during periods when few employees are present).

Personal Protective Equipment
Use of PPE is generally considered the last line of defense because it places the burden of hazard control directly on the worker. Its use should be limited to
- the period necessary to install, evaluate, or repair engineering controls;
- work situations such as maintenance and repair activities and hazardous waste and emergency response operations in which engineering controls are not feasible;
- work situations in which engineering controls and supplemental work practice controls are not sufficient to reduce exposures to, or below, occupational exposure limits;
- emergency or escape situations.

d. Discuss development of a schedule for the implementation of control measures.

According to DOE-STD-6005-2001, where applicable, a detailed schedule (that also addresses regular progress reports) for the implementation of any required health hazard prevention and control measures, including any long-term abatement and interim control measures, must be developed.

e. Discuss how the occupational health aspects of a required task, and the imposition of controls and their related costs necessary for occupational health during the task, may affect management’s prioritization of work or the completion of work that is affected by that task.

The following is taken from DOE-DP-STD-3023-98.

Occupational health risk measures should account for relevant parameters critical to distinguishing between decision options. To accomplish this, the following parameters should be considered:
- Relevant hazards and contingent outcomes
- Likelihood of occurrence and severity of consequences
- Timing and duration

**Relevant Hazards**

Risk measures should consider relevant hazards or contingent outcomes associated with the decision options. The following list indicates some typical risk measures considered by risk-based priority systems—risk measures may be added or removed as determined by the end-user objective:

- Public health and safety (i.e., acute and chronic risks, including cancer risks)
- Worker health and safety
- Environmental impacts
- Security and safeguards
- Regulatory risks
- Implications for and risks to public assessment/perception
- Implications for and risks to science and technology capabilities
- Implications for and risks to science and technology scope/mission

In addition to considering the full population at risk, attention should be directed to subpopulations (including future generations) that may be particularly susceptible to such risks and/or may be more highly exposed.

**Likelihood and Severity**

Risk measures sensitive to likelihood and severity may be needed to properly distinguish high risks from low risks. Generally, risk is the likelihood of an adverse event with respect to impact on a decision objective and the consequence of that event. The risk of an adverse event may be high because (1) the likelihood of the event’s occurrence is very high, (2) the consequence of the event is very high, or (3) both likelihood and consequence are very high.

**Timing and Duration**

Several issues pertaining to risk timing and duration may be important in distinguishing between decision options. First, some decision options may be viable only when implemented within a limited time window; in contrast, other decision options may be implemented at any time. For example, a decision option intended to limit the spread of contamination into an aquifer may be technically much simpler if it is quickly implemented; thus, a potentially limited window of opportunity exists before the nature and magnitude of the risk associated with the decision option is fundamentally changed. Second, performance measures should distinguish between (1) decision options that produce benefits that accrue over time and (2) decision options that must be repeated or extended to produce lasting benefits.
15. Industrial hygiene personnel shall demonstrate an expert level knowledge of industrial hygiene programs.

a. Describe the major components of sound industrial hygiene programs.

The National Safety Council’s, Fundamentals of Industrial Hygiene states that the industrial hygiene program has a number of components usually beginning with a policy statement that outlines the organization’s commitment to employee health and safety. The written program contains elements for hazard recognition, evaluation and exposure assessment, hazard control, employee training and involvement, program evaluation, and documentation. The format of the program depends on a variety of factors, including the size and type of the organization, its management philosophy, the range of occupational hazards at the facility, and the available health and safety resources.

b. Discuss management of industrial hygiene resources.

The following is taken from the National Safety Council, Fundamentals of Industrial Hygiene.

Organizational responsibilities for the program should be clearly defined. Industrial hygiene may be part of the safety department or another department, or it may be a department by itself. There should be a statement, such as policy or other document, that clearly communicates health and safety responsibilities, including where the industrial hygiene program gets its authority and to whom it reports. The success of safety and industrial programs requires the cooperation of many organizations and groups. A brief summary of the role each of the typical groups play follows.

Medical Program

Modern occupational health programs are ideally composed of elements and services designed to maintain the overall health of the work force and to prevent and control occupational and non-occupational diseases and injuries. A large corporation may have a full-time staff of occupational health physicians and nurses, equipped with a model clinic. A small manufacturer may rely on a nearby occupation health clinic. Medical programs usually offer the following services:

- Health examinations
- Diagnosis and treatment
- Medical recordkeeping
- Medical or biological monitoring
- Health education and counseling
- Wellness activities
- Medical case management

Engineering

Engineering professional are involved with the design and modification of manufacturing processes and facilities supporting these processes. Because these processes may introduce health and safety hazards into the workplace, engineers must coordinate their plans with the safety professional and the industrial hygienist.
Safety
The safety professional and industrial hygienist are concerned with the same goal: maintaining a safe and healthful workplace. Because safety programs tend to be older and more established than industrial hygiene programs, industrial hygiene is often part of the safety department.

The safety professional’s main responsibility is to run an effective safety program. An effective safety program lends credibility and builds support for all health- and safety-related work at the facility. The written safety program also enhances the safety program’s recognition of industrial hygiene issues and will work them into such safety activities as workplace inspections, accident investigations, and accident trend analysis and make appropriate referrals to the industrial hygienist. If industrial hygiene staffing is limited, safety professionals may accept responsibility for the implementation of the industrial hygiene program at their facility.

Purchasing
The purchasing department has the responsibility to ensure that only equipment and material approved by the industrial hygiene, safety, environmental, or other responsible reviewing organization are purchased. Purchasing should obtain material safety data sheets for all chemicals purchased.

General Manager
General managers have the ultimate responsibility for the industrial program and the safety of their employees at their facilities. They must ensure that their facilities comply with applicable corporate policies and government regulations by providing the necessary resources and support that they need to be successful.

Supervisor
The supervisor is a key person in the implementation and maintenance of safety and health requirements on a day-to-day basis. Their responsibilities include setting a good example, ensuring that safety and health rules are followed, ensuring that employees are provided training concerning potential safety and health hazards and control measures associated with their jobs, ensuring that all necessary personal protective equipment is provided and used, ensuring that employees receive all required medical examinations, and promptly reporting any operations or conditions that might present a hazard to employees.

Employees
Employees have the responsibility to perform their work in a manner that ensures their own personal safety as well as the safety of fellow employees. Employees must notify their supervisor’s immediately of hazardous work conditions or work practices, observe all safety and health rules, properly use and maintain personal protective equipment and other safety devices, maintain their work area in a neat and clean manner, and immediately report all accidents and near-miss incidents.
c. **Discuss the impact of legal requirements.**

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Health standards are promulgated under the OSH Act by the Department of Labor with technical advice from NIOSH.

Most of the safety and health standards now in force under the OSH Act for general industry were promulgated 30 days after the law went into effect on April 28, 1971. They represented a compilation of material authorize by the act from existing Federal, state, and consensus standards. These, with some amendments, deletions, and addition, remain the body of standards under the OSH Act.

The act prescribes procedures for use by the Secretary of Labor in promulgating regulations. It is of special interest that the 1968 ACGIH threshold limit values for exposures to toxic materials and harmful agents have been adopted in the regulations and have the effect of law. Although procedures are given for measuring exposure levels to specific material and agents in the standards promulgated by the Department of Labor, professional skills and judgments are still required in applying the intent of the many aspects of the act.

d. **Discuss the implications of noncompliance.**

The following is taken from the National Safety Council, *Fundamentals of Industrial Hygiene*.

Noncompliance may be found in the establishment. In that case, citations may be issued and civil penalties may be proposed. In order of significance, these are the types of violations or conditions normally considered.

*Imminent Danger*

An imminent danger is a condition where there is reasonable certainty a hazard exists that can be expected to cause death or serious physical harm immediately or before the hazard can be eliminated through regular procedures. If the employer fails to abate such conditions immediately, the compliance officer, through his or her area director, can go directly to the nearest Federal district court for legal action as necessary.

*Serious Violations*

A serious violation has a substantial probability that death or serious physical harm could result and that the employer knew, or should have known, of the hazard. An example is the absence of point-of-operations guards on punch presses or saws. A serious penalty may be adjusted downward based on the employer’s good faith, history of previous violations, and the size of the business.

*Willful Violations*

A willful violation exists where the evidence shows either an intentional violation of any standard, rule, or order or an indifference to requirements. The determination of whether to
issue a citation for a willful or repeated violation often raises difficult issues of law and policy and requires the evaluation of complex situation.

**Criminal/Willful Violations**
An employer who willfully violates any standard, rule, or order, if that violation caused death to any employee, will on conviction be punished by a fine or by imprisonment for not more than 6 months, or both. If the conviction is for a violation committed after a first conviction, the punishment will be a fine or imprisonment for not more than 1 year, or both.

**Repeated Violations**
An employer may be cited for a repeated violation if that employer has been cited previously for a substantially similar condition and the citation has become a final order. Generally, similar conditions can be demonstrated by showing that in both situations the identical standard was violated.

**Repeated Versus Willful**
Repeated violations differ from willful violations in that they may result from an inadvertent, accidental, or ordinarily negligent act. If a repeated violation also meets the criteria for willfulness, but not clearly so, a citation for a repeated violation is normally issued.

**Egregious Citations**
Cases under consideration for treatment as egregious must be classified as willful and meet one of the following criteria:

- The violations resulted in a worker fatality, a worksite catastrophe, or a large number of injuries or 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.
- The employer has committed a large number of violations so as to undermine significantly the effectiveness of any safety and health program in place.

**Other-Than-Serious Violations**
Other-than-serious violations are those that have a direct relationship to job safety and health but probably would not cause death or serious physical harm, such as tripping hazards. A non-serious penalty may be adjusted downward depending on the severity of the hazard, the employer’s good faith, his or her history of previous violations, and the size of the business.

**De Minimis**
A de minimis violation is a condition that has no direct or immediate relationship to job safety and health.

If respirators and other personal protective equipment are not properly fitted or are not worn and the affected employee is exposed to a toxic agent above the PEL, a citation will be issued, classified as serious.
Employers may be cited for an other-than-serious violation if, for example, they have not established written operating procedures governing the use of respirators, have not trained and instructed employees in their proper use, or have not regularly cleaned and disinfected the respirators even though such respirators are properly fitted and worn.

e. Discuss how industrial hygiene programs relate to other environmental, safety, and health programs, and to the broad goals of protecting not only the worker, but also the public and the environment.

The following is taken from DOE-STD-6005-2001.

DOE and contractor line management are required to coordinate industrial hygiene efforts with cognizant occupational medical, environmental protection, health physics, and work planning professionals.

Coordination must be established, maintained, and documented between the industrial hygiene staff and other worker protection and organizational functions in the facility to ensure the successful implementation and efficacy of the Worker Protection Program. These functions include, but are not limited to: occupational medicine, epidemiology, industrial safety, environmental protection, fire protection, health physics, purchasing, maintenance, engineering, operations, contracting, quality assurance, and employee groups and recognized bargaining units. For example, the senior industrial hygienist may recommend employees to be included in medical surveillance and should participate in the review of occupational exposure and medical surveillance data. (See also DOE G 440.1-2, section 4.2; DOE G 440.1-3, sections 4.3, 4.4.2, 4.5.2.1, and 4.6.2; and DOE G 440.1-4, section 4.7.1.)

f. Describe typical performance indicators and measures of success and completeness in an industrial hygiene program.

The following is taken from the National Safety Council, Fundamentals of Industrial Hygiene.

Typically, a young or immature program will focus on reactive activities such as incidents or new legal/regulatory requirements. As a program matures, more time will be spent in the planning phase of the Demming cycle determining ways for continual improvements, voluntary commitments, and preventive actions. The establishment of a strategic plan for long- and short-range goals and objectives is vital to the development of an effective industrial hygiene program. These goals and objectives should also be part of the written program. They are often established by a committee, such as a joint labor-management health and safety committee.

A goal is a desired outcome, whereas an objective is a specific activity or means of achieving a goal. Goals should be realistic and, when possible, measurable. For example, if ergonomics-related injuries are a problem, the goal may be to reduce the number of accidents by 25 percent within a three-year period. The objectives/activities to achieve this goal could include establishing an ergonomics committee, providing ergonomic training for the committee and affected personnel, and selecting an ergonomics consulting firm to provide
initial workplace surveys. Goals and objectives should not be static—they should be evaluated and updated regularly. The evaluation process may determine that the objectives are inadequate or that the goals are not well enough defined. In addition, as conditions change, there may be new problems to address, in which case new goals and objectives should be developed. The written program thus becomes a continually updated document.

g. Discuss the various types of industrial hygiene surveys (baseline, walkthroughs, periodic, etc.).

The following is taken from DOE-STD-6005-2001.

_Baseline Survey_

DOE and contractor line management are required to ensure that initial (or baseline) surveys are conducted of all work areas or operations to identify and evaluate potential worker health risks.

An effective worker protection program needs to include documented initial and periodic evaluations of all workplaces for the purposes of anticipating, identifying, evaluating, and controlling occupational health hazards. Such evaluations should be comprehensive, documented, and should:

- describe the work or task performed;
- identify the potentially exposed workers;
- identify and describe potential sources of hazardous agents;
- evaluate the controls used to prevent or minimize exposure;
- assess the level(s) of exposure;
- include a conclusion, with rationale, whether the identified agent(s), their use(s), and the potential exposures they cause pose a hazard to workers (i.e., generate a positive or negative exposure assessment);
- recommend additional controls for hazardous agents where necessary;
- recommend the scope and frequency of further exposure monitoring, as appropriate.

Note: The minimum set of hazardous agents generally to be considered are those identified in the ACGIH’s _Threshold Limit Values for Chemical Substances and Physical Agents_ and applicable OSHA regulations.

A comprehensive set of industrial hygiene evaluations, also known as the comprehensive industrial hygiene survey, can be generated by a single survey effort covering all work areas and operations or be the compilation of evaluations of these areas conducted over a period of time. The first complete evaluation of each operation is usually considered its baseline and is used for comparison with the results of future evaluations and exposure monitoring. The comprehensive survey ensures that all areas and operations are evaluated by an industrial hygienist and those evaluations are documented and accessible for future use by cognizant line management and worker health and safety professionals. Baselines must be updated periodically with the frequency of updates being determined by risk and variability of operations.
To promote the integration of worker protection efforts, the following groups or information resources should be consulted/utilized when planning industrial hygiene evaluations and/or considering exposure controls:

- Other worker protection staff (e.g., industrial safety professionals, health physicists)
- Occupational medical staff
- Environmental protection staff
- Line management
- Workers and worker representatives
- Existing chemical and hazard inventories
- Applicable written worker protection programs, such as respiratory, hazard communication, ergonomics, lead, beryllium, confined space, and hearing conservation
- Injury and illness logs/databases and trending tools like CAIRS and ORBITT/ORPS.

**Periodic Reassessments**

DOE and contractor line management are required to ensure that periodic resurveys and/or exposure monitoring are conducted, as appropriate.

The frequency that evaluations are updated should be proportional to the risk presented by the hazard(s), the variability of the operation, the operation frequency, and the type and dependability of the controls limiting exposures. As a general rule:

- Industrial areas/activities (e.g., fabrication or processing operations, craft shops) should be evaluated at least annually, and more often if appropriate and/or when potentially serious health hazards are present.
- Newly introduced or modified operations should be evaluated before starting or resuming operations, or when significant changes are made in adjacent work areas.
- Frequently changing work sites/operations (e.g., research and development facilities, construction sites, hazardous waste cleanup activities, decommissioning operations) should be evaluated as often as necessary to reliably characterize health risks.

16. **Industrial hygiene personnel shall demonstrate a working level knowledge of professional and ethical issues.**

   a. Discuss legal issues affecting the practice of industrial hygiene, including confidentiality of medical data and restraint of trade (antitrust).

The following is taken from Occupational Hazards, *AIHA Survey Identifies Nanotech, GHS as Top Issues.*

AIHA members’ top public policy issues for 2007–2008 are listed below.

**OSHA Issues**

Updating PELs—OSHA PELs are consensus-based limits that indicate how long an individual can be exposed to a particular substance without experiencing harmful effects. The occupational health and safety profession considers PELs to be one of the most basic tools needed to protect workers. However, many PELs have not been updated since the 1970s.
Science in this area has matured, but the PELs have not. AIHA continues to work with OSHA and others to reach a consensus on the best way to update the PELs.

Material safety data sheets (MSDSs)/Globally Harmonized System (GHS)—AIHA supports efforts to improve the accuracy of MSDSs and supports efforts to improve hazard communication for employers and employees. Such efforts also are a crucial element in protecting workers and others in case of national emergencies, according to AIHA. A major part of improving hazard communication is adoption of GHS, a measure that AIHA supports.

Nanotechnology—The increased use of nanotechnology for consumer products raises concerns that a clearer understanding is needed to accurately assess the occupational health and safety risks posed by working with this new technology. AIHA supports increased research into the possible hazards involved with nanotechnology.

Safety and health programs/injury and illness prevention programs—AIHA fully supports efforts to ensure that employers incorporate a written safety and health program into workplace policies.

Generic exposure assessment—AIHA supports continued guidance on the process used to determine exposure assessment. With the increased discussion about specific assessment strategies, AIHA will continue to monitor the discussions and work for assessment strategies that best protect workers.

Other OSHA issues that AIHA members find most important are hazard communication issues and pandemic preparation and response.

Legislative Issues

Updating PELs—Many of the PELs have not been updated at OSHA since the 1970s. According to AIHA, much of this is because of the regulatory process that, while providing for input from all stakeholders, stretches the process to a point where it takes a considerable number of years to update even one PEL. AIHA supports taking a closer look at whether or not a legislative solution may be achieved, whereby the process could be simplified for a small number of PELs that require updating.

Appropriations for OSHA, EPA, and NIOSH—According to AIHA, protection of workers and research and education efforts in support of worker health and safety are not possible without adequate Federal resources dedicated to the issue. While OSHA and NIOSH have fared reasonably well over the past several years, according to AIHA, continued concern over the Federal budget deficit could create the need to reduce expenditures in this area. AIHA believes that OSHA and NIOSH must remain adequately funded to carry out their statutory responsibility to ensure that every worker who goes to work returns home safe and healthy. AIHA also supports adequate funding for EPA.

Professional recognition/title protection—This issue continues to appear in the top public policy issues for AIHA, as it has since 1993. Professional recognition/title protection allows industrial hygienists and others who have met minimum educational and experience requirements (such as certified industrial hygienists and certified safety professionals) to be
legally defined and recognized as competent to perform certain work without the need for additional requirements. While some form of professional recognition/title protection legislation has been enacted in 19 states, AIHA continues to educate Federal and state policymakers about the importance of recognizing those professionals who have received education and certification from nationally recognized and accredited organizations.

Emergency preparedness and response—AIHA supports legislative measures that further incorporate programs for emergency preparedness and response. AIHA believes that both federal and state legislation is needed to clearly define the kind of programs needed and the resources to put these programs in place.

Laboratory accreditation—According to AIHA, accredited laboratories are the best way to ensure that test samples of potential workplace hazards are analyzed correctly. AIHA continues working to see that the AIHA laboratory accreditation program is noted in federal and state legislation and regulation as one of the programs with national recognition and acceptance. There is also an increased need to have AIHA-accredited laboratories recognized on the international level.

Other legislative issues AIHA members find most important are GHS; expanding OSHA coverage to all public employees; and the legislative threat to limit the reference to the threshold limit values (TLVs).

**AIHA Issues**
In addition to public policy issues, AIHA members also ranked the top issues of overall importance to AIHA. The top association issues are
- the legislative, regulatory, and legal concerns regarding the TLVs;
- standards, whether they be from the ANSI or other standard-setting bodies;
- professional ethics;
- collaboration with other Office of Environmental Health and Safety organizations;
- GHS.

**Restraint of Trade**
The following is taken from AIHA, *Antitrust Guidelines*.

The following is a description of the Federal antitrust laws applicable to industrial hygiene activities and industrial hygiene organizations such as the AIHA.

There are two antitrust statutes that are of principal concern to individuals and firms who take part in nonprofit organizational activities: the Sherman Act and the Federal Trade Commission Act. These laws prohibit contracts, combinations, and conspiracies in restraint of trade. The Supreme Court has said that not every contract or combination in restraint of trade constitutes a violation; only those that unreasonably restrain trade are unlawful. Thus the courts will look at all of the facts and circumstances surrounding the conduct in question to determine whether it unreasonably restrains trade and therefore violates the laws.

Certain kinds of conduct are exclusively presumed to be unreasonable and therefore unlawful. Such conduct, which is considered to be unlawful per se, consists of certain
practices that clearly restrain competition and have no other redeeming benefits. Examples of such practices include
- agreements to establish price (price fixing)
- agreements to refuse to deal with third parties (boycotts)
- agreements to allocate markets or limit production
- tie-in sales that require the customer to buy an unwanted item in order to buy the product desired

Associations and other nonprofit membership organizations by their very nature present potential antitrust problems. One reason is that in bringing competitors together into an organization, there exists the means by which collusive action can be taken in violation of the antitrust laws. Since both the Sherman and Federal Trade Commission Acts prohibit combinations in restraint of trade, and since a membership organization by its very nature is a combination of competitors, one element of a possible violation is already present. Only the action to restrain trade must occur for there to be a violation.

Another special antitrust problem of a membership organization is that many of its valuable programs deal with subjects sensitive from an antitrust viewpoint: price reporting, product standards, certification, statistics, and customer relations.

Members of AIHA should refrain from any discussion that could provide the basis for an inference that the members agreed to take any action that might restrain trade. An “agreement” among members in antitrust terms is a very broad concept: it may be oral or written, formal or informal, expressed or implied. A “gentleman’s agreement” to “hold the line” on prices is more than sufficient to evidence an unlawful conspiracy to fix prices.

The basic principle to be followed in avoiding antitrust violations in connection with organization activity is to see that no illegal agreements, expressed or implied, are reached or carried out through the organization. Members should also avoid engaging in conduct that may give the appearance of an unlawful agreement.

The following is an excerpt from the Illinois Institute of Technology, Center for the Study of Ethics in the Professions at IIT, AIHA Code of Ethics for the Professional Practice of Industrial Hygiene.

Keep confidential personal and business information obtained during the exercise of industrial hygiene activities, except when required by law or overriding health and safety considerations.
- Industrial hygienists should report and communicate information that is necessary to protect the health and safety of workers and the community.
- If their professional judgment is overruled under circumstances where the health and lives of people are endangered, industrial hygienists shall notify their employer or client or other such authority, as may be appropriate.
- Industrial hygienists should release confidential personal or business information only with the information owners’ express authorization, except when there is a duty to disclose information as required by law or regulation.
b. Discuss ethical behavior in scientific data gathering and reporting.

The following is taken from the Illinois Institute of Technology, Center for the Study of Ethics in the Professions, AIHA Canons of Ethical Conduct and Interpretive Guidelines.

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

Industrial hygienists should base their professional opinions, judgments, interpretations of findings, and recommendations upon recognized scientific principles and practices which preserve and protect the health and well-being of people.

Industrial hygienists shall not distort, alter, or hide facts in rendering professional opinions or recommendations.

Industrial hygienists shall not knowingly make statements that misrepresent or omit facts.

c. Discuss personal ethical behavior, including the following:
   • Misrepresentation of qualifications and credentials
   • Conflict of interest

The following is taken from AIHA Code of Ethics.

Misrepresentation of Qualifications and Credentials
As professionals in the field of industrial hygiene, American Board of Industrial Hygienists certificants and candidates have the obligation to maintain high standards of integrity and professional conduct; accept responsibility for their actions; continually seek to enhance their professional capabilities; practice with fairness and honesty; and encourage others to act in a professional manner consistent with the certification standards and responsibilities set forth below.

Responsibilities to ABIH, the profession and the public
   • Certificant and candidate compliance with all organizational rules, policies, and legal requirements.
   • Comply with laws, regulations, policies, and ethical standards governing professional practice of industrial hygiene and related activities.
   • Provide accurate and truthful representations concerning all certification and recertification information.
   • Maintain the security of ABIH examination information and materials, including the prevention of unauthorized disclosures of test information.
   • Cooperate with ABIH concerning ethics matters and the collection of information related to an ethics matter.
• Report apparent violations of the ethics code by certificants and candidates upon a reasonable and clear factual basis.
• Refrain from public behavior that is clearly in violation of professional, ethical, or legal standards. Industrial hygienists shall affix or authorize the use of their seal, stamp, or signature on a document only when the document is prepared by the industrial hygienists or someone under their direction and control.

Conflict of interest
• Disclose to clients or employers significant circumstances that could be construed as a conflict of interest or an appearance of impropriety.
• Avoid conduct that could cause a conflict of interest with a client, employer, employee, or the public.
• Assure that a conflict of interest does not compromise legitimate interests of a client, employer, employee, or the public and does not influence or interfere with professional judgments.
• Refrain from offering or accepting significant payments, gifts or other forms of compensation or benefits in order to secure work or that are intended to influence professional judgment.

17. Industrial hygiene personnel shall demonstrate a familiarity level knowledge of the principal external committees, agencies, and associations relating to the field of industrial hygiene.

a. Describe the purpose and significance of the following:
  • American Industrial Hygiene Association (AIHA)
  • American Conference of Governmental Industrial Hygienists (ACGIH)
  • American Board of Industrial Hygiene (ABIH)
  • American National Standards Institute (ANSI)
  • American Society of Safety Engineers (ASSE)
  • American Society of Testing Materials (ASTM)
  • Center for Disease Control (CDC)
  • Environmental Protection Agency (EPA)
  • Factory Mutual (FM) or Underwriters Laboratories (UL)
  • Mine Safety and Health Administration (MSHA)
  • National Fire Protection Association
  • National Institute for Occupational Safety and Health (NIOSH)
  • National Institute of Health (NIH)
  • Occupational Safety and Health Administration (OSHA)

[Note: ASTM, American Society for Testing and Materials is now known as ASTM International.
CDC stands for Centers for Disease Control and Prevention.
NIH stands for National Institutes of Health.]
The following is taken from each organization’s Web site.

*American Industrial Hygiene Association (AIHA)*

AIHA promotes healthy and safe environments by advancing the science, principles, practice, and value of industrial hygiene and occupational and environmental health and safety.

*American Conference of Governmental Industrial Hygienists (ACGIH)*

The best known of ACGIH’s activities is the Threshold Limit Values for Chemical Substances Committee, established in 1941. This group was charged with investigating, recommending, and annually reviewing exposure limits for chemical substances. It became a standing committee in 1944. Two years later, the organization adopted its first list of 148 exposure limits, then referred to as maximum allowable concentrations. The term “threshold limit values (TLVs)” was introduced in 1956. The first documentation of the TLVs was published in 1962 and is now in its seventh edition. Today’s list of TLVs includes 642 chemical substances and physical agents, as well as 38 biological exposure indices for selected chemicals.

Two other ACGIH committees have created publications that are recognized as the preeminent professional references in their respective fields: *Industrial Ventilation: A Manual of Recommended Practice*, first published in 1951, and *Air Sampling Instruments (ASI) for Evaluation of Atmospheric Contaminants*, which debuted in 1960. The ventilation manual is now in its 26th edition and the ASI manual is in its 9th edition.

The other ACGIH committees have also published valuable professional reference texts, including the following:

- *Bioaerosols: Assessment and Control* (1999)
- *Particle Size—Selective Sampling for Particulate Air Contaminants* (1999)
- *Biological Monitoring of Exposure to Industrial Chemicals* (1990)

ACGIH offers approximately 400 publication titles, including their well-known Signature Publications. Topics include industrial hygiene; environment, safety, and health; toxicology; medical issues; hazardous materials/waste; workplace controls; indoor air quality; physical agents; ergonomics; computer resources; downloadable TLV and biological exposure indices (BEI) documentation; and professional development. All of ACGIH’s publications can be ordered online at [http://acgih.org/store](http://acgih.org/store).

In addition to producing publications, ACGIH has supported numerous educational activities that facilitate the exchange of ideas, information, and techniques. These courses, symposia, and workshops are all vehicles for achieving the ultimate goal of worker health and safety.

Over the years, the topics have included cotton dust exposures, workplace control of carcinogens, industrial hygiene for mining and tunneling, asbestos identification and measurement, and others. The ACGIH also holds seminars and conferences on bloodborne pathogens and sharps injuries, air sampling, industrial ventilation, bioaerosols, mining, occupational exposure databases, mold remediation, and other topics.
ACGIH also has a professional learning center that offers courses, workshops, and symposia.

_American Board of Industrial Hygiene (ABIH)_

The ABIH, a not-for-profit corporation, was organized to improve the practice and educational standards of the profession of industrial hygiene.

The activities they are presently engaged in for carrying out this purpose are as follows:

- Offering certification examinations to industrial hygienists with the required educational background and professional industrial hygiene experience
- Acknowledging individuals who successfully complete the examination by issuing a certificate
- Requiring diplomates to maintain their certification by submitting evidence of continued professional development
- Maintaining records and publishing a roster of certificate holders for the profession and the public

_American National Standards Institute (ANSI)_

ANSI is a private, nonprofit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system.

The institute’s mission is to enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems and safeguarding their integrity.

_American Society of Safety Engineers (ASSE)_

Founded in 1911, ASSE is the oldest and largest professional safety organization. Its more than 30,000 members manage, supervise, and consult on safety, health, and environmental issues in industry, insurance, government, and education. ASSE is guided by a 16-member Board of Directors, which consists of 8 regional vice presidents; 3 council vice presidents; Society president; president-elect; senior vice president; vice president of finance; and executive director. ASSE has 13 practice specialties, 152 chapters, 31 sections, and 52 student sections.

_American International (ASTM)_

ASTM International is one of the largest voluntary standards development organizations in the world—a trusted source for technical standards for materials, products, systems, and services. Known for their high technical quality and market relevancy, ASTM International standards have an important role in the information infrastructure that guides design, manufacturing, and trade in the global economy.

ASTM International, originally known as the American Society for Testing and Materials (ASTM), was formed over a century ago, when a forward-thinking group of engineers and scientists got together to address frequent rail breaks in the burgeoning railroad industry. Their work led to standardization on the steel used in rail construction, ultimately improving railroad safety for the public. As the century progressed and new industrial, governmental, and environmental developments created new standardization requirements, ASTM answered
the call with consensus standards that have made products and services safer, better, and more cost-effective. The proud tradition and forward vision that started in 1898 is still the hallmark of ASTM International.

Today, ASTM continues to play a leadership role in addressing the standardization needs of the global marketplace. Known for its “best in class” practices for standards development and delivery, ASTM is at the forefront in the use of innovative technology to help its members do standards development work, while also increasing the accessibility of ASTM International standards to the world.

ASTM continues to be the standards forum of choice of a diverse range of industries that come together under the ASTM umbrella to solve standardization challenges. In recent years, stakeholders involved in issues ranging from safety in recreational aviation, to fiber optic cable installations in underground utilities, to homeland security, have come together under ASTM to set consensus standards for their industries.

Standards developed at ASTM are the work of over 30,000 ASTM members. These technical experts represent producers, users, consumers, government, and academia from over 120 countries. Participation in ASTM International is open to all with a material interest, anywhere in the world.

Centers for Disease Control and Prevention (CDC)

CDC, as the sentinel for the health of people in the United States and throughout the world, strives to protect people’s health and safety, provide reliable health information, and improve health through strong partnerships.

CDC Mission
The mission of the CDC is to promote health and quality of life by preventing and controlling disease, injury, and disability.

CDC seeks to accomplish its mission by working with partners throughout the nation and the world to

- monitor health
- detect and investigate health problems
- conduct research to enhance prevention
- develop and advocate sound public health policies
- implement prevention strategies
- promote healthy behaviors
- foster safe and healthful environments
- provide leadership and training

Those functions are the backbone of CDC’s mission. Each of CDC’s component organizations undertakes these activities in conducting its specific programs. The steps needed to accomplish this mission are also based on scientific excellence, requiring well-trained public health practitioners and leaders dedicated to high standards of quality and ethical practice.
Environmental Protection Agency (EPA)
The mission of the EPA is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people.

EPA employs 18,000 people across the country. EPA’s headquarters offices are in Washington, D.C., and it has 10 regional offices and more than a dozen labs. The staff are highly educated and technically trained; more than half are engineers, scientists, and policy analysts. In addition, a large number of employees are legal, public affairs, financial, information management, and computer specialists. EPA is led by the Administrator, who is appointed by the president of the United States.

Factory Mutual (FM) or Underwriters Laboratories (UL)
Factory Mutual is an organization of a group of insurers composed of mutual property and casualty insurance companies, a subsidiary stock insurance company, and a subsidiary safety engineering company. Their objective is to provide insurance and safety engineering services for large manufacturing companies, substantial housing projects, public institutions, and educational institutions. Coverage includes the perils of fire, explosion, windstorm, riot, civil commotion, sprinkler leakage, malicious mischief, damage to vehicles, and damage to aircraft. Field offices staffed by salaried personnel deal directly with insureds; there is no agency field force.

Underwriters Laboratories
Underwriters Laboratories Inc. (UL) is an independent product safety certification organization that has been testing products and writing standards for safety for over a century. UL evaluates more than 19,000 types of products, components, materials, and systems annually, with 21 billion UL Marks appearing on 71,000 manufacturers’ products each year. UL’s worldwide family of companies and network of service providers includes 66 laboratory, testing, and certification facilities serving customers in 104 countries.

UL’s mission: Working for a safer world since 1894
- To promote safe living and working environments for people by the application of safety science and hazard-based safety engineering
- To support the production and use of products which are physically and environmentally safe and to apply our efforts to prevent or reduce loss of life and property
- To advance safety science through research and investigation
- To concentrate our efforts and resources on public safety in those areas where we can make valuable contributions
- To work with integrity and a focus on quality to enhance the trust conveyed by our certification marks
- To charge fair prices that allow us to meet our obligations, sustain our growth, and invest in safety science and education.
- To invest in our people and encourage our people to invest in themselves
- To be a good example of corporate citizenship and social responsibility
Mine Safety and Health Administration (MSHA)
The mission of the MSHA is to administer the provisions of the Federal Mine Safety and Health Act of 1977 (Mine Act) and to enforce compliance with mandatory safety and health standards as a means to eliminate fatal accidents, reduce the frequency and severity of nonfatal accidents, minimize health hazards, and promote improved safety and health conditions in the nation’s mines.

National Fire Protection Association (NFPA)
The mission of the international nonprofit NFPA is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. NFPA membership totals more than 81,000 individuals from around the world and more than 80 national trade and professional organizations.

Established in 1896, the NFPA serves as the world’s leading advocate of fire prevention and is an authoritative source on public safety. In fact, NFPA’s 300 codes and standards influence every building, process, service, design, and installation in the United States, as well as many of those used in other countries. NFPA’s focus on true consensus has helped the association’s code-development process earn accreditation from ANSI.

National Institute of Occupational Safety and Health (NIOSH)
NIOSH is the Federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. NIOSH is part of the CDC in the Department of Health and Human Services, and is an agency established to help ensure safe and healthful working conditions for working men and women by providing research, information, education, and training in the field of occupational safety and health. NIOSH provides national and world leadership to prevent work-related illness, injury, disability, and death by gathering information, conducting scientific research, and translating the knowledge gained into products and services. NIOSH’s mission is critical to the health and safety of every American worker.

National Institutes of Health (NIH)
The National Institutes of Health (NIH), a part of the U.S. Department of Health and Human Services, is the primary Federal agency for conducting and supporting medical research.

Helping to lead the way toward important medical discoveries that improve people’s health and save lives, NIH scientists investigate ways to prevent disease as well as the causes, treatments, and even cures for common and rare diseases.

Occupational Safety and Health Administration (OSHA)
OSHA’s mission is to assure the safety and health of America’s workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health.

OSHA and its state partners have approximately 2,100 inspectors, plus complaint discrimination investigators, engineers, physicians, educators, standards writers, and other
technical and support personnel spread over more than 200 offices throughout the country. This staff establishes protective standards, enforces those standards, and reaches out to employers and employees through technical assistance and consultation programs.

18. Industrial hygiene personnel shall demonstrate the ability to evaluate the adequacy of local compliance or conformance with the following document sections:

- **10 CFR 850, Chronic Beryllium Disease Prevention Program**
- **10 CFR 851, Worker Safety and Health Program**
- **29 CFR 1910, occupational safety and health standards such as the following:**
  - Subpart C, Reserved
  - Subpart G, Occupational Health and Environmental Control
  - Subpart H, Hazardous Materials (including 1910.120, Hazardous Waste Operations and Emergency Response)
  - Subpart I, Personal Protective Equipment
  - Subpart J, General Environmental Controls (including 1910.146, Permit-Required Confined Spaces)
  - Subpart K, Medical and First Aid
  - Subpart Q, Welding, Cutting, and Brazing
  - Subpart Z, Toxic and Hazardous Substances

- **29 CFR 1926, safety and health regulations such as the following:**
  - Subpart D, Occupational Health and Environmental Controls
  - Subpart E, Personal Protective and Life Saving Equipment
  - Subpart H, Materials Handling, Storage, Use, and Disposal
  - Subpart J, Welding and Cutting
  - Subpart Y, Recordkeeping
  - Appendixes A & B to Subpart Y, Examples of Conditions Which May Restrict or Limit Exposure to Hyperbaric Conditions and Guidelines for Scientific Diving
  - Subpart Z, Toxic and Hazardous Substances

[Note: Subpart Y is Diving.]

- **Other Federal Regulations, such as the following:**
  - 10 CFR 830, Nuclear Safety Management
  - 10 CFR 830, Quality Assurance (specially section 122)
  - 10 CFR 835, Occupational Radiation Protection
  - 29 CFR 1960, Basic Program elements for Federal Employees
  - 40 CFR 763, Asbestos
  - 42 CFR 73, Select Agents and Toxins

- **Other industrial hygiene-related technical standards such as the following:**
  - DOE G 440.1-7A, Implementation Guide for Use with 10 CFR 850, Chronic Beryllium Disease Prevention Program
  - DOE M 231.1-1A, Environment, Safety, and Health Reporting Manual
  - ANSI Z88.2, Practices for Respiratory Protection
  - ANSI Z88, Respiratory Protection, Respirator Use, and Physical Qualifications for Personnel
  - ANSI Z136.1, Safe Use of Lasers
a. Describe the purpose, scope, and application of the requirements or guidelines detailed in the listed document sections.

10 CFR 850, “Chronic Beryllium Disease Prevention Program”
Title 10 XFR 850 implements a chronic beryllium disease prevention program for DOE. This program will reduce the number of workers currently exposed to beryllium at DOE facilities managed by DOE or its contractors, minimize the levels of, and potential for, exposure to beryllium, establish medical surveillance requirements to ensure early detection of disease, and improve the state of information regarding chronic beryllium disease and beryllium sensitization.

10 CFR 851, “Worker Safety and Health Program”
The worker safety and health requirements in 10 CFR 851 govern the conduct of contractor activities at DOE sites.

This rule establishes the following:
- Requirements for a worker safety and health program that reduces or prevents occupational injuries, illnesses, and accidental losses by providing DOE contractors and their workers with safe and healthful workplaces at DOE sites; and
- Procedures for investigating whether a violation of a requirement of this rule has occurred, for determining the nature and extent of any such violation, and for imposing an appropriate remedy.

29 CFR 1910, “Occupational Safety and Health Standards”
- Subpart C, Reserved
  As of this writing there is no content in Subpart C of 29 CFR 1910.
  o Part 1910.94 contains antiquated ventilation requirements that, in general, will not be enforced unless the potential for overexposure is demonstrated.
  o Part 1910.95 contains detailed requirements for noise control and hearing conservation.
  o Part 1910.97 contains antiquated requirements for nonionizing radiation and is superseded by other mandatory DOE guidance.
- Part 1910.106 contains requirements for the safe storage of flammable and combustible materials.
- Part 1910.107 contains the requirements for ventilation during the spray finishing of flammable materials.
- Part 1910.120 contains detailed requirements for the development and implementation of a comprehensive safety and health program at hazardous waste cleanup sites, and also contains requirements for hazardous material cleanup responders.

Subpart I, “Personal Protective Equipment”
- Part 1910.132 contains general requirements for the use of personal protective equipment, its selection, and the training of personnel in its use.
- Part 1910.133 contains requirements for the selection and use of eye and face protection.
- Part 1910.134 contains quite general and very antiquated requirements for the selection and use of respiratory protection (more useful guidance is found in ANSI Z88.2 and Z88.6).
- Part 1910.138 contains requirements for the selection and use of hand protection.

Subpart J, “General Environmental Controls” (including 1910.146, “Permit-Required Confined Spaces”)
- Part 1910.146 requires the establishment of permit-required confined space entry programs, and includes the requirements for the listing of required spaces; the training of personnel with functions related to entry; the development, use, and maintenance of a permitting system; and the performance of monitoring prior to entry, and sometimes during occupancy.

Subpart K, “Medical and First Aid”
- Part 1910.151 lists general requirements relating to medical services and the requirement for eyewashes in certain work places.

Subpart Q, “Welding, Cutting, and Brazing”
- Parts 1910.252–254 list requirements relating to welding including the use of eye and face protection and screens, the separation of flammable and combustible materials from the welding operation, and antiquated ventilation requirements.

Subpart Z, “Toxic and Hazardous Substances” (including 1910.1020, “Access to Employee Exposure and Medical Records”)
- Parts 1910.1000–1050 contain OSHA PELs for chemical substances and comprehensive standards for specific chemical compounds.
- Part 1910.1200 contains detailed requirements for the communication of information related to the potential hazards of chemicals used in the work place.
- Part 1910.1450 contains requirements for safety and health programs for laboratories.
29 CFR 1926, “Safety and Health Regulations for Construction”

- Subpart D, “Occupational Health and Environmental Controls”
  - Part 1926.56 contains antiquated illumination requirements for construction work places (more current guidance for recommended lighting for any work environment is found in the Illuminating Engineering Society’s, Lighting Handbook, current edition).

- Subpart E, “Personal Protective and Life Saving Equipment”
  - Part 1926.103 contains general and antiquated requirements for the use of respiratory protection in construction work places (more useful guidance is found in ANSI Z88.2 and Z88.6).

- Subpart H, “Materials Handling, Storage, Use, and Disposal”
  - Part 1926.250 contains requirements for storage.

- Subpart J, “Welding and Cutting”
  - Part 1926.354 contains requirements relating to welding, including the requirement that toxic coatings be removed to within four inches of the point of hot work.

- Subpart Y, “Recordkeeping”
  [Note: The standard indicates that this subpart is “Recordkeeping.” Subpart Y is “Diving.” The following is related to diving.]

Although these parts are included in 29 CFR 1926, the actual requirements are listed in 29 CFR 1910, subparts 420 through 427.
  - Part 1926.1071 contains the scope and application.
  - Part 1926.1072 contains definitions.
  - Part 1926.1076 contains the qualifications for a dive team.
  - Part 1926.1080 contains the safe practices manual.
  - Part 1926.1081 contains pre-dive procedures.
  - Part 1926.1082 contains the procedures used during the dive.
  - Part 1926.1083 contains post-dive procedures.
  - Part 1926.1084 contains the requirements related to SCUBA diving.
  - Part 1926.1085 contains the requirements related to surface-supplied air diving.
  - Part 1926.1086 contains the requirements related to mixed-gas diving.
  - Part 1926.1087 contains the requirements related to live boating.

- Appendixes A and B to Subpart Y, “Examples of Conditions Which May Restrict or Limit Exposure to Hyperbaric Conditions and Guidelines for Scientific Diving”
  - Appendix A includes examples of conditions which may restrict or limit exposure to hyperbaric conditions.
  - Appendix B includes guidelines for scientific diving.

- Subpart Z, “Toxic and Hazardous Substances”
  - Subpart Z contains OSHA expanded standards governing exposure to hazardous chemicals that are, in general, comparable to general industry requirements.
Other Federal Regulations

- **10 CFR 830, “Nuclear Safety Management”**
  10 CFR 830 governs the conduct of DOE contractors, DOE personnel, and other persons conducting activities, including providing items and services that affect, or may affect, the safety of DOE nuclear facilities.

- **10 CFR 830.122, “Quality Assurance Requirements”**
  10 CFR 830.122 contains the criteria for management and performance assessments of quality assurance programs.

- **10 CFR 835, “Occupational Radiation Protection”**
  The rules in 10 CFR 835 establish radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from the conduct of DOE activities.

  Section 1960 of the Occupational Safety and Health Act (the Act) contains special provisions to assure safe and healthful working conditions for Federal employees. Under that section, it is the responsibility of the head of each Federal agency to establish and maintain an effective and comprehensive occupational safety and health program that is consistent with the standards promulgated under section 6 of the Act. The Secretary of Labor (the Secretary), under section 1960, is to report to the President certain evaluations and recommendations with respect to the programs of the various agencies. The duties that section 24 of the Act imposes on the Secretary of Labor extend to the collection, compilation, and analysis of occupational safety and health statistics from the Federal government. The role of the General Services Administration in this area stems from its duties as the government’s principal landlord and from its specific safety and health responsibilities under 41 CFR part 101, subchapter C, Federal Property Management Regulations.

- **40 CFR 763, “Asbestos”**
  Note: Subparts A through D and Subparts F and H are reserved. Subpart G only contains 3 questions. Subpart E applies to asbestos containing materials in schools.

- **42 CFR 73, “Select Agents and Toxins”**
  42 CFR 73 implements the provisions of the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 setting forth the requirements for possession, use, and transfer of select agents and toxins. The biological agents and toxins listed in this part have the potential to pose a severe threat to public health and safety, to animal health, or to animal products. Overlap select agents and toxins are subject to regulation by the CDC and the Animal and Plant Health Inspection Service.

Other Industrial Hygiene-Related Technical Standards

- **DOE-STD-6005-2001, Industrial Hygiene Practices**
The purpose of DOE-STD-6005-2001 is to assist DOE and its contractors in the development, implementation, and integration of recognized industrial hygiene practices within the overall worker protection program that are consistent with the policy objectives and requirements of DOE O 440.1B and the integrated safety management system.

It gives practical guidance relating to the anticipation, recognition, evaluation, and control of occupational health hazards at DOE facilities. These basic principles may also be appropriate and useful for many transient activities such as hazardous waste operations, environmental restoration operations, or scientific research and development activities. However, the short, dynamic nature of many of these activities may make traditional baselining and periodic reevaluations impractical. Paragraph 7 of this standard provides additional guidance for these situations.

- **DOE G 440.1-7A, Implementation Guide for Use with 10 CFR 850, Chronic Beryllium Disease Prevention Program**
  The purposes of DOE G 440.1-7A are to provide supplemental information and describe implementation practices to assist responsible employers in effectively developing, managing, and implementing a chronic beryllium disease prevention program that is consistent with requirements specified in 10 CFR 850, “Chronic Beryllium Disease Prevention Program.” 10 CFR 850 is promulgated pursuant to DOE authority under section 161 of the Atomic Energy Act of 1954.

  Specifically, this guide discusses the regulatory requirements of 10 CFR 850, provides cross-references to DOE directives and industry consensus standards that contain detailed guidance for implementing specific requirements in 10 CFR 850, and provides explanations, with examples, of how to meet the basic requirements for developing and implementing a chronic beryllium disease prevention program.

- **DOE M 231.1-1A, Environment, Safety, and Health Reporting Manual**
  DOE M 231.1-1A provides detailed requirements to supplement DOE O 231.1A, Environment, Safety and Health Reporting.

- **ANSI Z88.2, American National Standard for Respiratory Protection**
  ANSI Z88.2 sets forth accepted practices for respirator users; provides information and guidance on the proper selection, use, and care of respirators; and contains requirements for establishing and regulating respirator programs. The standard covers the use of respirators to protect persons against the inhalation of harmful air contaminants and against oxygen-deficient atmospheres in the workplace.

- **ANSI Z88.6, Respiratory Protection, Respirator Use, and Physical Qualification for Personnel**
  [Note: The following are updates of the current sections of ANSI Z88.6.]
  Z88.6: ANSI/AIHA Z88.6 2006 Respirator - Physical Qualifications for Personnel
  ANSI Z88.6 provides information and guidance to physicians or other licensed health care professionals to assist them in determining the medical suitability of personnel for respirator use. A TeleWeb was presented on October 18, 2006 by the
Z88 and Z88.6 subcommittee members to provide a comprehensive review of ANSI/AIHA Z88.6 2006 on evaluating the medical suitability of workers to use respiratory protective devices.

- **ANSI Z136.1, American National Standard for Safe Use of Lasers**  
  ANSI Z136.1 provides recommendations for the safe use of lasers and laser systems that operate at wavelengths between 180 nm and 1 mm.

- **ANSI Z358.1, American Standard for Emergency Eyewash and Shower Equipment**  
  ANSI Z358.1-2004 provides detailed information for emergency eyewash and shower equipment. Revised in 2004, ANSI Z358.1-2004 has been enhanced and provides greater understanding on several issues, e.g., tepid temperature, personal eyewash units, distance/time to reach units, installation requirements, etc. This standard differentiates between the various types of eyewash and shower equipment available and the specific requirements for each type.

- **ANSI C95.1, Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz**  
  [Note: The correct title of ANSI 95.1 is Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.]

  IEEE C95.1-1991 gives recommendations to prevent harmful effects in human beings exposed to electromagnetic fields in the frequency range from 3 kHz to 300 GHz. The recommendations are intended to apply to exposures in controlled, as well as uncontrolled, environments. They are not intended to apply to the purposeful exposure of patients by or under the direction of practitioners of the healing arts. The recommendations at 300 GHz are compatible with existing recommendations of safe exposure in the infrared frequency range (starting at 300 GHz). A rationale that describes how the recommendations were arrived at, and the factors taken into account in formulating them, is included.

- **ACGIH TLV Booklet, American Conference of Governmental Industrial Hygienists, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices**  
  The information in The TLV Booklet is used worldwide as a guide for evaluation and control of workplace exposures to chemical substances and physical agents. TLV occupational exposure guidelines are recommended for more than 700 chemical substances and physical agents. There are more than 50 BEIs that cover more than 80 chemical substances. Chemical abstract service registry numbers are listed for each chemical. Introductions to each section and appendices provide philosophical bases and practical recommendations for using TLVs and BEIs.

- **ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes**  
  This standard covers all aspects of safety and health in the welding environment, emphasizing oxygen gas arc welding processes with some coverage given to resistance welding. It contains information on protection of personnel and the general area, ventilation, fire prevention and protection, and confined spaces. A significant
section is devoted to precautionary information, showing examples, and an extensive bibliography.

b. Discuss what constitutes acceptable contractor work performance consistent with the requirements or guidelines of the above regulations and technical standards.

The following is taken from DOE O 226.1A.

As contracting officers, DOE line management must periodically evaluate contractor performance in meeting contractual requirements and expectations.

- A combination of DOE line management oversight, contractor self-assessments, and other performance indicators (e.g., performance measures and event reports) must be used to evaluate contractor performance.
- DOE line management must evaluate the effectiveness of management programs, including environment, safety, and health; and industrial hygiene. Poor performance in these areas must have significant negative consequences on evaluations and fee determination. In accordance with contract provisions, evaluations must be used to reward significant accomplishments and/or performance improvements.
- Quantitative performance indicators and measures may be used to support the evaluation of a contractor; however, such indicators provide only a partial indication of system effectiveness and must be considered in combination with assessment results.
- Evaluations must be based on an analysis of the results of relevant information obtained or developed during the performance period, including contractual performance measures and objectives, DOE line management oversight, contractor self-assessments, operational history/events, and reviews by DOE and external organizations.

c. Using selected sections from 29 CFR 1910, 29 CFR 1926, and technical standards, prepare an action plan that adequately outlines interviews and observations to conduct, and details documents to review, during an evaluation of contractor compliance or conformance against the requirements of the selected sections.

d. Using an appropriate level of coverage for demonstration purposes, evaluate contractor compliance with the requirements of selected sections of 29 CFR 1910, 29 CFR 1926, and technical standards. During this evaluation, demonstrate the ability to conduct interviews, make observations, and review documents properly.

e. Given data from an evaluation, analyze the results of the evaluation to determine contractor compliance or conformance with the requirements or guidelines.

f. Given the results from an analysis of contractor compliance or conformance, document and communicate the results to contractor and Department line management.

Elements c through f of this competency are performance-based. The Qualifying Official will evaluate their completion.
19. Industrial hygiene personnel shall demonstrate the ability to determine the adequacy of local compliance or conformance with the industrial hygiene-related sections and/or requirements of DOE Orders such as the following:

- DOE O 151.1C, Comprehensive Emergency Management System
- DOE M 231.1-1A, Environment, Safety, and Health Reporting Manual
- DOE M 231.1-2, Occurrence Reporting and Processing of Operations Information
- DOE O 226.1A, Implementation of Department of Energy Oversight Policy
- DOE O 225.1A, Accident Investigations
- DOE O 440.1B, Worker Protection Program for DOE (including the National Nuclear Security Administration) Federal Employees
- DOE O 414.1C, Quality Assurance
- DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities
- DOE O 442.1A, Department of Energy Employee Concerns Program

a. Describe the purpose, scope, and application of the requirements or guidelines detailed in the listed Orders and guides with respect to industrial hygiene.

**DOE O 151.1C, Comprehensive Emergency Management System**

The objectives of DOE O 151.1C are

- To establish policy and to assign and describe roles and responsibilities for the DOE Emergency Management System. The Emergency Management System provides the framework for development, coordination, control, and direction of all emergency planning, preparedness, readiness assurance, response, and recovery actions. The Emergency Management System applies to DOE and to NNSA.
- To establish requirements for comprehensive planning, preparedness, response, and recovery activities of emergency management programs or for organizations requiring DOE/NNSA assistance.
- To describe an approach to effectively integrate planning, preparedness, response, and recovery activities for a comprehensive, all-emergency management concept.
- To integrate public information and emergency planning to provide accurate, candid, and timely information to site workers and the public during all emergencies.
- To promote more efficient use of resources through greater flexibility (i.e., the graded approach) in addressing emergency management needs consistent with the changing missions of the Department and its facilities.
- To ensure that the DOE Emergency Management System is ready to respond promptly, efficiently, and effectively to any emergency involving DOE/NNSA facilities, activities, or operations, or requiring DOE/NNSA assistance.
- To integrate applicable policies and requirements, including those promulgated by other Federal agencies (e.g., stockpiling stable iodine for possible distribution as a radiological protective prophylaxis) and interagency emergency plans into the Department’s Emergency Management System.
- To eliminate duplication of emergency management effort within the Department.

**DOE M 231.1-1A, Environment, Safety, and Health Reporting Manual**

DOE M 231.1-1A supplements DOE O 231.1A and provides detailed requirement for implementing DOE reporting requirements, including time schedules for reporting and data elements to be reported. The page change modifies policy previously established that
requires recording and reporting occupational injuries and illnesses of subcontractors employees.

*DOE M 231.1-2, Occurrence Reporting and Processing of Operations Information*

DOE M 231.1-2 provides detailed information for reporting occurrences and managing associated activities at DOE facilities, including NNSA facilities.

*DOE O 226.1A, Implementation of Department of Energy Oversight Policy*

DOE O 226.1A provides direction for implementing DOE P 226.1A, *Department of Energy Oversight Policy*, which establishes DOE policy for assurance systems and processes established by DOE contractors and oversight programs performed by DOE line management and independent oversight organizations. The objective of the Order is to ensure that contractor assurance systems and DOE oversight programs are comprehensive and integrated for key aspects of operations essential to mission success.

*DOE O 225.1A, Accident Investigations*

The objective of DOE O 225.1A is to prescribe requirements for conducting investigations of certain accidents occurring at DOE operations and sites; to prevent the recurrence of such accidents; and to contribute to improved environmental protection and safety and health of DOE employees, contractors, and the public.

*DOE O 440.1B, Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*

DOE O 440.1B establishes the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE/NNSA Federal workers with a safe and healthful workplace.

*DOE O 414.1C, Quality Assurance*

DOE O 414.1C ensures that the quality of DOE/NNSA products and services meets or exceeds the customers’ expectations.

*DOE Order 5480.19, Chg. 2, Conduct of Operations Requirements for DOE Facilities*

The purpose of DOE Order 5480.19 is to provide requirements and guidelines for Departmental elements, including the NNSA, to use in developing directives, plans, and/or procedures relating to the conduct of operations at DOE facilities. The implementation of these requirements and guidelines should result in improved quality and uniformity of operations.

*DOE O 442.1A, Department of Energy Employee Concerns Program*

As a service to all departmental elements, the following will be to establish a DOE Employee Concerns Program that ensures employee concerns related to such issues as the environment, safety, health, and management of DOE and the NNSA programs and facilities are addressed through
prompt identification, reporting, and resolution of employee concerns regarding DOE facilities or operations in a manner that provides the highest degree of safe operations;

- free and open expression of employee concerns that results in an independent, objective evaluation; and

- supplementation of existing processes with an independent avenue for reporting concerns.

b. Discuss what constitutes acceptable contractor compliance and work performance consistent with the requirements and recommendations of the Orders and guides above.

The following is taken from DOE O 226.1A.

As contracting officers, DOE line management must periodically evaluate contractor performance in meeting contractual requirements and expectations:

- A combination of DOE line management oversight, contractor self-assessments, and other performance indicators (e.g., performance measures and event reports) must be used to evaluate contractor performance.

- DOE line management must evaluate the effectiveness of management programs, including environment, safety, and health; and industrial hygiene. Poor performance in these areas must have significant negative consequences on evaluations and fee determination. In accordance with contract provisions, evaluations must be used to reward significant accomplishments and/or performance improvements.

- Quantitative performance indicators and measures may be used to support the evaluation of a contractor; however, such indicators provide only a partial indication of system effectiveness and must be considered in combination with assessment results.

- Evaluations must be based on an analysis of the results of relevant information obtained or developed during the performance period, including contractual performance measures and objectives, DOE line management oversight, contractor self-assessments, operational history/events, and reviews by DOE and external organizations.

c. Using an appropriate level of coverage for demonstration purposes, evaluate contractor compliance with the requirements or guidelines of the selected Orders. During this evaluation, demonstrate the ability to conduct interviews, make observations, and review documents properly.

d. Given data from an evaluation, analyze the results of the evaluation to determine contractor compliance or noncompliance with the requirements.
e. Given the results from an analysis of contractor compliance or noncompliance, document and communicate the results to contractor and Department line management.

Elements c through e of this competency are performance based. The Qualifying Official will evaluate their completion.

20. Industrial hygiene personnel shall demonstrate a working level knowledge of assessment performance, including assessment planning and the use of field observations, employee interviews, and document reviews in the assessment of industrial hygiene performance.

a. Describe the role of an industrial hygienist with respect to oversight of contractor-operated DOE facilities and operations.

According to the National Safety Council’s, Fundamentals of Industrial Hygiene, the industrial hygienist carries out detailed studies of incidents; prepares recommendations and other reports; reviews new processes, machinery, and layouts from a health viewpoint; promotes occupational health and safety education; and advises management about health hazards, industrial hygiene practices, procedures, and equipment needs.

b. Describe the assessment requirements and limitations associated with the Federal interface with contractor employees.

As assessment requirements and limitations associated with the interface of industrial hygiene personnel and contractor employees vary from site to site, the local Qualifying Official will evaluate the completion of this element.

c. Complete at least one assessment in accordance with the local DOE procedures, practices, and expectations. The scope of the assessment shall encompass site-specific methods of hazard analysis and employee exposure assessment.

This element is performance based. The Qualifying Official will evaluate its completion.

21. Industrial hygiene personnel shall demonstrate the ability to prepare assessment reports that document assessment results, support assessment conclusions, and clearly communicate conclusions and recommendations for corrective action.

a. Distinguish between compliance-based and performance-based assessments.

According to DOE G 414.1-2A, compliance-based assessments focus on verification of adherence to established requirements. Performance-based assessments are conducted on activities and processes that relate directly to performance expectations and that emphasize safety and reliability.

b. Complete an assessment appraisal report. The appraisal report shall be completed in the local DOE format or in accordance with local procedures,
practices, and expectations. The report shall demonstrate specific knowledge of the site’s methods of hazard analysis and employee exposure assessment.

This element is performance based. The Qualifying Official will evaluate its completion.

22. Industrial hygiene personnel shall demonstrate the ability to trend and analyze industrial hygiene-related information.

   a. Identify and discuss the principal performance indicators that are normally used to review industrial hygiene performance and effectiveness.

   Injury and illness logs/databases and trending tools like CAIRS and ORBITT/ORPS are generally used to review industrial hygiene performance and effectiveness.

   b. Trend and analyze relevant facility operations information and discuss the relationship of operations information to industrial hygiene performance.

   This element is performance based. The Qualifying Official will evaluate its completion.

23. Industrial hygiene personnel shall demonstrate a working level knowledge of the interrelationship between quality assurance programs and industrial hygiene.

   a. Describe how an industrial hygiene program may be evaluated for quality assurance activities, including the following:
      ▪ Industrial hygiene program procedures
      ▪ Sampling methods and chain of custody
      ▪ Laboratory accreditation
      ▪ Evaluation and maintenance of documentation
      ▪ Independent verification
      ▪ Technical staff qualifications

   The following is taken from DOE-STD-6005-2001.

   Management should annually perform and document a self-assessment to ensure the effectiveness of the implementation of industrial hygiene practices and assure quality. Such self-assessments should include reviews of
      ▪ the adequacy and use of industrial hygiene resources;
      ▪ all exposure assessment records, including medical exposure data, audiometric testing records, illness and injury logs and supporting information, and any other records relevant to the maintenance of industrial hygiene functions;
      ▪ compliance with applicable industrial hygiene requirements and established performance measures;
      ▪ success in receiving and responding to employee occupational health concerns;
      ▪ industrial hygiene evaluation records to assess progress in abating health hazards;
      ▪ all required written programs that include industrial hygiene elements (e.g., the hazard communication program and the respiratory protection program);
      ▪ training program effectiveness.
24. Industrial hygiene personnel shall demonstrate the ability to apply recognized technical practices and guidance properly to DOE non-industrial or non-repetitive work activities.

a. Apply DOE Orders and standards logically and appropriately to environmental management and restoration sites.

b. Apply industrial hygiene technical practices to the DOE Integrated Safety Management (ISM) initiative and its validations.

c. Research and apply best management practices to emerging occupational health concerns that are not well regulated (Research and Development, nanotechnology)

Elements a through c of this competency are performance based. The Qualifying Official will evaluate their completion.
Selected Bibliography and Suggested Reading

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American National Standards Institute (ANSI)
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ANSI BSR AIHA Z88.12 (Draft) Respiratory Protection for Infectious Aerosols.
ANSI Z87.1, Occupational and Educational Personal Eye and Face Protection Devices. 2003.

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)

**American Society of Mechanical Engineers (ASME)**

Food and Agriculture Organization of the United Nations, FAO Corporate Document Repository, Quality of Analytical Procedures.

**International Organization for Standardization**


**National Institute for Occupational Safety and Health (NIOSH)**
- Safety and Health Topic, *Asthma and Allergies.*
- *Worklife Initiative, Program Description.*


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- Safety Issues on the Table. December 12, 2006.


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- Secretary of Energy’s June 4, 2001 memorandum, *100 percent Quality Assurance Testing of HEPA Filters at the DOE Filter Test Facility (FTF)*.

**U.S. Department of Health and Human Services**
- Centers for Disease Control, *Microbiology Biosafety*, table 3B.

**U.S. Department of Labor, Occupational Safety and Health Administration (OSHA)**
- *How to File a Complaint with OSHA. Medical Screening and Surveillance*. “What is Screening and Where Can Information About Screening Methods be Found?”
Occupational Safety and Health Guideline for Mercury Vapor.
OSHA TED 01-00-015, Technical Manual.

U.S. Environmental Protection Agency (EPA)
Chain of Custody Procedures for Samples and Data.
Technology Transfer Network Support Center for Regulatory Atmospheric Modeling,
Guideline on Air Quality Models.

U.S. National Institutes of Health, National Cancer Institute
Definitions of Cancer Terms.

U.S. National Library of Medicine and the National Institutes of Health, MedlinePlus,
Medical Encyclopedia
Cirrhosis. May 4, 2006
Jaundice. August 18, 2006.

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