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Executive Summary

The Research Laboratory Safety Guidebook was developed as part of a multi-volume set of guidebooks to assist Department of Veterans Affairs (VA) facilities enhance their occupational safety and health and environmental programs. This guidebook is written for Occupational Safety and Health staff, Industrial Hygienists, and Research Laboratory staff, and includes guidelines and best practices applicable to VA Facilities within the scope of Veterans Health Administration (VHA) and federal requirements. Additionally, it contains sample forms and templates, fact sheets, and references and resources for background information. The goals of this publication are to increase knowledge of compliance and recognition of research laboratory hazards; and assist in developing/enhancing research laboratory safety programs.

The Research Laboratory Safety Guidebook covers three distinct subject areas. The first part focusses on chemical safety, including introduction to chemical safety; hazard communication; and associated research laboratory equipment, engineering controls, and best practices. The second part addresses biological, physical, and radiation safety for the research laboratory. The final part covers animal colony safety, research laboratory decommissioning, risk reduction, and environmental management.

Each chapter presents a general discussion of the section topic. Whenever possible, a URL to a website or VA's intranet site is provided for additional information or when further information is warranted. References to commercial products or services are intended to enhance the topic content and are not an endorsement of any product or service. Each sub-heading within the chapter incorporates practical information, guidelines, and best practices as seen at VHA research laboratories from around the country. At the end of each chapter, a list of resources and enclosures is provided for quick reference.

The chapters in the Research Laboratory Safety Guidebook include:

Chapter 1: Research Laboratory Safety: Roles and Responsibilities
Chapter 2: Research Laboratory Safety: Risk Assessment
Chapter 3: Hazard Communication
Chapter 4: Management of Hazardous Chemicals in Research Laboratories
Chapter 5: Chemical Safety in Research Laboratories
Chapter 6: Research Laboratory Ventilation
Chapter 7: Biological Safety in Research Laboratories
Chapter 8: Physical Safety in Research Laboratories
Chapter 9: Radiation Safety in Research Laboratories
Chapter 10: Working Safety with Research Animals
Chapter 11: Special Topics: Lasers and Nanoparticles
Chapter 12: Research Laboratory Closeout and Decommissioning
Chapter 13: Environmental Management in Research Laboratories

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Update Listing

The following list identifies online updates for this guidebook. It is designed to assist the reader in verifying the most current information available.

Date Updated	Remarks	Chapter

Acronyms and Abbreviations

Acronym/Abbreviation	Definition
$(NH_4)_2Cr_2O_7$	Ammonium Dichromate
$(NH_4)_2S_2O_8$	Ammonium Persulfate
°C	Degrees Celsius
°F	Degrees Fahrenheit
µCi	microCurie
µl	microliter
µm	micrometers
^{14}C	Carbon-14
^{51}Cr	Chromium-51
^{3}H	Tritium/Hydrogen-3
^{3}He	Helium-3
^{125}I	Iodine-125
^{131}I	Iodine-131
^{133}I	Iodine-133
2-ME	2-Mercaptoethanol
^{32}P	Phosphorus-32
^{32}S	Sulfur-32
^{33}S	Sulfur-33
^{125}Te	Tellurium-125
^{131}Xe	Xenon-131
AAALAC	Association for Assessment and Accreditation of Laboratory Animal Care International
ABSL	Animal Biosafety Level
ACGIH®	American Conference of Governmental Industrial Hygienists

ACH	Air Change Per Hour
ACM	Asbestos-Containing Material
ACORP	Animal Component of Research Protocol
ACOS	Associate Chief of Staff
ACOS/R	Assistant Chief of Staff for Research
ACUP	Animal Care and Use Program
AED	Automated External Defibrillator
AFFF	Aqueous Film-Forming Foam
Ag_2O	Silver Oxide
$AgNO_3$	Silver Nitrate
AIHA	American Industrial Hygiene Association
ALI	Annual Limit of Intake
ALK	Alkali
ALRA	As Low As Reasonably Achievable
AMCA	Air Moving Control Association
ANSI	American National Standards Institute
AO	Administrative Officer
APC	Asbestos Program Coordinator
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASISTS	Automated Safety Incident Surveillance and Tracking System
ATSDR	Agency for Toxic Substances & Disease Registry
AWA	Animal Welfare Act
AWE	Annual Workplace Evaluation
$Ba(ClO_2)_2$	Barium Chlorite
$Ba(ClO_4)_2$	Barium Perchlorate

$Ba(NO_3)_2$	Barium Nitrate
BCME	Bis-Chloromethyl Ether
BEI	Biological Exposure Index
BMBL	Biosafety in Microbiological and Biomedical Laboratories
BME	Beta Mercaptoethanol
BO_4^3	Perborate
BP	Boiling Point
Bq	Becquerel
Br_2	Bromine
BrO_4	Bromate
BSC	Biological Safety Cabinet
BSL	Biological Safety Level
BSO	Biological Safety Officer
$C_{21}H_{20}N_3Br$	Ethidium Bromide
C_2H_2O	Ethylene Oxide
C_3H_5NO	Acrylamide
$C_4H_{10}O$ or $(C_2H_6)_2O$	Diethyl Ether
$C_6H_4(CH_3)_2$	Xylene
$C_6H_5CH_3$	Toluene
C_6H_5OH	Phenol
C_6H_6	Benzene
CaO	Calcium Oxide
CAS	Chemical Abstracts Service
CAV	Constant Air Volume
cc	cubic centimeters
CDC	Centers for Disease Control and Prevention

CDRH	Center for Devices and Radiological Health
CEDE	Committed Effective Dose Equivalent
CFH	Chemical Fume Hood
cfm	Cubic feet per minute
CFM	Office of Construction & Facilities Management
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CH_2CL_2	Methylene Chloride
CH_3-Hg-CH_3	Dimethyl Mercury
CHO	Chemical Hygiene Officer
CHP	Chemical Hygiene Plan
Ci	Curie
ClO	Hypochlorite
ClO_2	Chlorite
ClO_3	Chlorate
ClO_4	Perchlorate
cm	centimeter
cm^2	square centimeter
CMO	Chief Medical Officer
CMOP	Consolidated Mail Outpatient Pharmacy
CMS	Carbon Molecular Sieve
CNS	Central Nervous System
CO_2	Carbon Dioxide
COR	Corrosive
COR	Contracting Officer’s Representative
COS	Chief of Staff
cpm	counts per minute

CPR	Cardiopulmonary Resuscitation
CR(IV)	Chromium
Cr(VI)	Chromium Hexavalent
$Cr_2O_7^{2-}$	Dichromate
CRADO	Chief Research and Development Officer
CrO_3	Chromium (VI) Trioxide
CrO_4^{2-}	Chromate
CRY or CRYO	Cryogenics
dB	Decibel
DBCP	dibromochloropropane
DEA	Drug Enforcement Agency
DES	diethylstilbestrol
DHHS	Department of Health and Human Services
DMSO	Dimethyl Sulfoxide
DNA	Deoxyribonucleic Acid
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
dpm/cm_2	disintegration per minute per square centimeter
DTLVS	Documentation of the Threshold Limit Values for Substances
EHS	Environment, Health, and Safety Office
ELF	Extremely Low Frequency
EMF	Electric and Magnetic Fields
EMR	Electromagnetic Radiation
EMS	Environmental Management Service

EO	Executive Order
EOC	Environment of Care
EOHP	Employee Occupational Health Program
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
EtBr	Ethidium Bromide
EtO	Ethylene Oxide
F_2	Fluorine
FAA	Federal Aviation Administration
FAQ	Frequently Asked Questions
FCC	Federal Communications Commission
FDA	Food and Drug Administration
Fe_2O_3	Ferric Trioxide
$FeCl_3$	Ferric Chloride
FMS	Facilities Management Service
FP	Flash Point
fpm	feet per minute
FRP	Fiberglass Reinforced Plastic
FSE	Flexible Slot Exhaust
FSP	Field Sampling Plan
ft_3	cubic feet
FV	Face Velocity
g	gram
g/cc	grams per cubic centimeter
GAO	General Accounting Office
GEMS	Green Environmental Management System
GFCI	Ground Fault Circuit Interrupter

GHS	Globally Harmonized System (of Classification and Labeling of Chemicals)
GHz	Gigahertz
GI	Gastrointestinal
GM	Geometric Mean
G-M	Geiger-Müller
GSD	Geometric Standard Deviation
GTA	Glutaraldehyde
Gy	gray
H_2CrO_4	Chromic Acid
H_2O_2	Hydrogen Peroxide
H_2SO_4	Sulfuric Acid
HAC	Hazardous Air Contaminant
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HBV	Hepatitis B Virus
HCHO	Formaldehyde
$HClO_4$	Perchloric Acid
HCP	Hazard Communication Program
HCP	Hearing Conservation Program
HCS	Hazard Communication Standard
HCV	Hepatitis C Virus
HDPE	High-Density Polyethene
HEPA	High-Efficiency Particulate Air
HF	Hydrofluoric Acid
Hg	Mercury

HHS	Department of Health and Human Services
HIO_4 or H_5IO_6	Periodic Acid
HIV	Human Immunodeficiency Virus
HMIS	Hazardous Materials Identification System
HMR	Hazardous Materials Regulations
HMTA	Hazardous Materials Transportation Act
HNO_3	Nitric Acid
HP	High Performance
HPD	Hearing Protection Device
HPLC	High-Performance Liquid Chromatography
HPPOS	Health Physics Positions
hr	hour
HRPP	Human Research Protection Program
$HSCH_2CH_2OH$	Mercaptoethanol
HTLC	Highly Toxic Laboratory Chemicals
HVAC	Heating, Ventilation, and Air Conditioning
IACUC	Institutional Animal Care and Use Committee
IAQ	Indoor Air Quality
IARC	International Agency for Research on Cancer
IATA	International Air Transport Association
IBC	Institutional Biosafety Committee
ICP-AES	Inductively Coupled Plasma-Atomic Emission Spectroscopy
IDE	Investigational Drug Exemption
IDLH	Immediately Dangerous to Life and Health
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

IO_3	Iodate
IO_4^-	Iodic
IPMP	Integrated Pest Management Program
IR	Infrared
IRB	Institutional Review Board
IRIS	Integrated Risk Information System
ISO	International Organization for Standardization
JHA	Job Hazard Analysis
$K_2Cr_2O_7$	Potassium Dichromate
K_2CrO_4	Potassium Chromate
$K_2S_2O_8$	Potassium Persulfate
kg	kilogram
kHz	kilohertz
KIO_3	Potassium Iodate
$KMnO_4$	Potassium Permanganate
KNO_3	Potassium Nitrate
kPa	kilopascal
LAA	Laboratory Animal Allergy
LAI	Laboratory-Acquired Infection
lb	pound
LC	Lethal Concentration
LD	Lethal Dose
LEL	Lower Explosive Limit
LEP	Laser Eye Protection
LEV	Local Exhaust Ventilation
LFL	Lower Flammable Limit
LLMW	Low-Level Mixed Waste

LLRW	Low-Level Radioactive Waste
LSC	Liquid Scintillation Counter
LSC	Laser Safety Committee
LSO	Laser Safety Officer
LSP	Laser Safety Program
LVMP	Laboratory Ventilation Management Program
m^3	cubic meters
MC	Methylene Chloride
mCi	milliCurie
MDVA	Multi-Disciplinary Vulnerability Assessment
mg	milligram
mg/m^3	milligrams per cubic meter
MgO	Magnesium Oxide
MHz	megahertz
ml	milliliter
mm	millimeter
mmHg	millimeter of mercury
MML	Master Materials License
mmole	millimole
MMWR	Morbidity and Mortality Weekly Report
MnO_4^-	Permanganate
MOT	Materials of Trade
MOU	Memorandum of Understanding
MPE	Maximum Permissible Exposure
MPTP	1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine
mR	milliroentgen
mrem	millirem

MRI	Magnetic Resonance Imaging
MW	Molecular Weight
mW	milliWatts
MW	megaWatts
N_2O_x	Nitrogen Oxide
$Na_2Cr_2O_7$	Sodium Dichromate
NA2O	Sodium Oxide
$Na_2S_2O_8$	Sodium Persulfate
NaClO	Sodium Hypochlorite Solution
$NaIO_3$	Sodium Iodate
$NaIO_4$	Sodium Periodate
NaK	Sodium-Potassium
$NaMnO_4$	Sodium Permanganate
$NaNO_2$	Sodium Nitrite
NASPHV	National Association of State Public Health Veterinarians
NCI	National Cancer Institute
Nd:YAG	Neodymium:Yttrium-Aluminum-Garnet
NDZ	No Diffuser Zone
NF	National Formulary
NFPA®	National Fire Protection Association
NF_x	Nitrogen Fluorides
NH_4NO_3	Ammonium Nitrate
NHPP	National Health Physics Program
NHZ	Nominal Hazard Zone
NIH	National Institutes of Health
NIOSH	National Institute of Occupational Safety and Health

NIST	National Institute of Standards Technology
nm	nanometer
NMR	Nuclear Magnetic Resonance
NO_3^-	Nitrate
NOEL	No Observable Effect Level
NRC	Nuclear Regulatory Commission
NRC	National Research Council
NRSC	National Radiation Safety Committee
NSF	National Sanitation Federation
NTP	National Toxicology Program
O_2	Oxygen
OAL	Office of Acquisitions and Logistics
OBA	Office of Biotechnology Activities
OCAMES	Office of Capital Asset Management, Engineering, and Support
$OCH(CH_2)_3CHO$	Glutaraldehyde
OEL	Occupational Exposure Limit
OIG	Office of the Inspector General
OSL	Optically Stimulated Luminescence
-O-O-	Double Oxygen
ORD	Office of Research and Development
ORO	Office of Research Oversight
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OXY	Oxidizer
PEL	Permissible Exposure Limit
PHI	Protected Health Information

PHS	Particularly Hazardous Substances
PHS	Public Health Service
PPE	Personal Protective Equipment
ppm	parts per million
psi	pounds per square inch
PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride
PVS	Polyvinyl Steel
QAPP	Quality Assurance Project Plan
R	Roentgen
R&D	Research and Development
rad	radiation absorbed dose
RC	Research Coordinator
RCEP	Research Compliance Education Program
RCF	Refractory Ceramic Fiber
RCHO	Research Chemical Hygiene Officer
RCO	Research Compliance Officer
RCRA	Resource Conservation and Recovery Act
RCS	Records Control Schedule
rDNA	Recombinant DNA
REL	Recommended Exposure Limit
rem	roentgen equivalent man
RF	Radio Frequency
RIPP	Research Information Protection Program
RNA	Ribonuleic Acid
rpm	revolutions per minute
RPP	Respiratory Protection Program

RPSS	Research Protocol Safety Survey
RSC	Research Safety Coordinator
RSC	Radiation Safety Committee
RSO	Radiation Safety Officer
$S_2O_8^{2-}$	Persulfate
SA	Simple Asphyxiant
SAFE	Safety Automated Facility Evaluation
SAP	Sampling and Analysis Plan
SAR	Specific Absorption Rate
SDS	Safety Data Sheet
SEG	Similarly Exposed Group
SI	Système International
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SO_5	Peroxymonosulfate
SOP	Standard Operating Procedure
SRS	Subcommittee on Research Safety
STEL	Short-Term Exposure Limit
STOT-RE	Specific Target Organ Toxicity-Repeated Exposure
STOT-SE	Specific Target Organ Toxicity-Single Exposure
Sv	Sievert
T	Tritium
TAB	Test, Adjustment, and Balance
TCLP	Toxicity Characteristic Leaching Procedure
TIL	Technical Information Library
TiO_2	Titanium Dioxide
TLV®	Threshold Limit Value

TMS	Talent Management System
TSDF	Treatment, Storage, and Disposal Facility
TV	Terminal Velocity
TWA	Time-Weighted Average
UEL	Upper Explosive Limit
UFC	Uniform Fire Code
UFL	Upper Flammable Limit
UN	United Nations
UN GHS	United Nations' Globally Harmonized System (of Classification and Labeling of Chemicals)
USC	United States Code
USDA	United States Department of Agriculture
USP	United States Pharmacopeia
UV	Ultraviolet
VA	Department of Veterans Affairs
VAMC	VA Medical Center
VAV	Variable Air Volume
VBE	Ventilated Balance Enclosure
VDT	Video Display Terminal
VE	Variable Exhaust
vfag	average face velocity
VHA	Veterans Health Administration
VISN	Veterans Integrated Service Network
VMO	Veterinary Medical Officer
VP	Vapor Pressure
~~W~~	Reacts Violently with Water
W	Watt

~~W OX~~	Reacts Violently with Water and Oxidizers
W/cm_2	Watts per square centimeter
WAG	Waste Anesthetic Gas
WG	Water Gage
WHO	World Health Organization
WOC	Without Compensation

Research Laboratory Safety: Roles and Responsibilities

1.1. Introduction

The following chapter describes the roles and responsibilities of program offices and staff that support safety and industrial hygiene functions in research laboratories at Veterans Health Administration (VHA) facilities. The chapter also provides guidance for some key issues that may impact safety programs in research laboratories.

Establishing an effective service-level safety program is a complicated process that requires interaction between various staff (medical center, university affiliates, and private research foundations), as well as service-level and facility committees and subcommittees. Research programs require the support of several Department of Veterans Affairs Medical Center (VAMC) services, departments, and/or entities, such as Facilities Management Service (FMS), Occupational Safety and Health (OSH), Employee Occupational Health, Biological Safety, Infection Control, Radiation Safety, Laser Safety, VA Security, and Environmental Management Service (EMS), as well as other relevant local safety experts/committees. A clear understanding of the VHA organizational structure that includes well-defined roles and responsibilities for Research Service staff is critical to establishing a successful program.

1.2. VHA Organizational Overview

The VHA Research Program involves VHA Central Office, medical centers, academic affiliates, other federal agencies, non-profit organizations, and the private industry. VHA Research Programs and practices are reviewed by national and local offices including:

- The Office of Research Oversight (ORO): The principle VHA office that advises the Under Secretary for Health in regards to compliance and assurance in research programs.
- The Office of Research and Development (ORD): The office that establishes national polices for all research activities in VHA facilities and reports to the Deputy Under Secretary for Health for Policy and Services. Research Programs are aligned under ORD.
- The National Center for Ethics in Health Care: The primary VHA office that addresses complex ethical issues and serves as a resource for research ethics.
- The Office of Occupational Safety, Health, and Green Environmental Management System (GEMS) Programs: The office that reports to the

Assistant Deputy Under Secretary for Health for Policy and Services and oversees the implementation of occupational safety, industrial hygiene, life safety, and GEMS Programs throughout the 21 Veterans Integrated Service Networks (VISNs).

- VISN and VAMC OSH offices: The offices responsible for developing and sustaining safety programs at the local level. The VISN assesses the implementation of research safety programs through annual workplace evaluations (AWEs). Ultimately, all facilities with research laboratory functions are responsible for administering effective safety programs that address organizational structures, staffing levels, the complexity of the Research Program, and the type of research being conducted.

1.2.1. ORO

Mandated by legislation in 2003, ORO reports directly to the Under Secretary for Health and provides programmatic oversight on research compliance and assurance concerns, including human subject protections, laboratory animal welfare, research laboratory safety, research laboratory security, research information security, research laboratory misconduct, debarment for research laboratory impropriety, and other matters that the Under Secretary for Health may assign. ORO is also responsible for developing and conducting Research Compliance Officer education programs as directed by the Under Secretary for Health. ORO has working relationships with VISNs and VHA facilities, and serves as the VA liaison to other federal agencies, such as the Department of Health and Human Services (HHS), U.S. Department of Agriculture (USDA), and the U.S. Department of Labor (DOL).

ORO is comprised of a central office and regional offices. ORO evaluates operational policies and procedures related to VHA research compliance with laws, regulations, and policies. The Central Office staff conducts routine reviews of VA Research Safety Programs and Animal Care and Use Programs (ACUPs), Research Information Protection Programs (RIPPs), Research Compliance Education Programs (RCEPs), and Research Misconduct. ORO staff identifies research compliance and assurance issues that could potentially result in adverse outcomes and ensures implementation of policies and procedures throughout VHA research facilities. The Regional Office personnel serve as subject matter experts for Human Research Protection Programs (HRPPs) and Research and Development (R&D) Committee program reviews. The Regional Offices conduct periodic routine or issue-driven site evaluations to identify problem areas and emergent compliance issues. ORO staff oversees implementation of abatement action plans for deficiencies identified during routine reviews and self-reports from facilities or other federal regulatory agencies. Information about ORO is available online at: http://www.va.gov/oro/.

1.2.2. ORD

The mission of ORD is to discover knowledge, develop VA researchers and health care leaders, and create innovations that advance health care for our Veterans and the nation. ORD develops policies, allocates funds, and creates and implements educational programs that support the research mission. ORD functions include providing consultative support to field research staff and funding opportunities to sustain research. ORD is organized into the following four services:

- Biomedical Laboratory Research and Development Service.
- Clinical Science Research and Development Service.
- Health Services Research and Development Service.
- Rehabilitation Research and Development Service.

ORD investigates all areas of Veterans health care concerns, and each service reports to the Chief Research and Development Officer (CRADO). The CRADO is responsible for the overall policy, planning, coordination, and direction of R&D activities within VHA. He or she reports to the Deputy Under Secretary for Health for Policy and Services and is responsible for the supervision of the four ORD research services directors. An organizational chart and additional information about ORD can be found online at: http://vaww.research.va.gov/default.cfm.

1.2.3. VISN Directors

It is the responsibility of VISN Directors to ensure that all VHA workers and volunteers within the VISN have a safe and healthful working environment and to guarantee employees' rights to report unsafe or unhealthful working conditions without fear of reprisal. VISN Directors are also responsible for monitoring compliance with various entities and regulatory agencies, including OSH requirements contained in federal laws, regulations, and Executive Orders (EOs); VA and VHA directives; and Union agreements. The VISN Director ensures that R&D committees and subcommittees are established by Facility Directors, that the committees are supported throughout the VISN, and that the programs are accredited by relevant external credentialing organizations.

The VISN Director monitors the status of the research OSH Program through AWEs conducted by VISN OSH Program Managers to identify hazardous worksite conditions in research laboratories and other areas of the VAMC. AWE findings are reported through the Facility Director to the Research Service. Abatement measures are coordinated through the facility Safety Office, and corrective actions are tracked by the VISN.

1.2.4. Facility Directors

Facility Directors are responsible for the implementation of all applicable safety policies and procedures in the Research Program as well as the establishment of all required research committees. The Facility Director ensures that staff, utilities, telephones, and information technology services are provided for research

programs and provides access to facility services, such as radiation safety, infection prevention and control, hazardous waste management, and facility engineering.

1.3. Associate Chief of Staff (ACOS)/R&D

The ACOS/R&D (or equivalent) is responsible for the proper functioning of all aspects of the Research Program at his or her designated site. At facilities with smaller research programs, a Research Coordinator (RC) may be assigned the ACOS/R&D duties as an adjunct function of another administrative position. The ACOS or the RC reports through the Chief of Staff (COS) or Chief Medical Officer (CMO) to the Facility Director and plays an important role in communicating safety-related information from the CRADO to appropriate personnel.

1.3.1. Research and Development Committee

As advised in VHA Handbook 1200.01, Research and Development (R&D) Committee, every VAMC involved in the conduct of research must have an R&D Committee of record to oversee all Research Service program functions. This committee serves at the facility level and is responsible through the COS to the Facility Director. The ACOS/R&D and the Administrative Officer (AO) for R&D assist the R&D Committee in the execution of its duties. The R&D Committee focuses on the overall local Research Service (rather than individual protocols) and assigns responsibilities for related issues, such as compliance, to more appropriate subcommittees and/or individuals at the facility. However, the R&D Committee is not limited to serving only as a local committee. A facility may share an R&D Committee with another facility, or a multi-site R&D Committee may be established to regionally serve multiple VHA facilities, through a written Memorandum of Understanding (MOU) that describes the roles and responsibilities of all parties. The R&D Committee may fulfill all R&D Committee responsibilities at another facility, including oversight of its subcommittees, but cannot serve as the R&D Committee of a non-VA institution.

To ensure effective oversight of the Research Program, the R&D Committee establishes several subcommittees that pertain to various aspects of research, including, but not limited to, care and use of research laboratory animals, human studies, and research safety. The R&D Committee is required to establish:

- A Subcommittee on Research Safety (SRS).
- An Institutional Biosafety Committee (IBC) if non-exempt recombinant deoxyribonucleic acid (rDNA) research subject to the National Institutes of Health (NIH) Guidelines is performed.
- An Institutional Animal Care and Use Committee (IACUC) if the research conducted involves the use of animals.
- An Institutional Review Board (IRB) if the research conducted involves human subjects.

Other subcommittees may be established to ensure effective and efficient oversight of the Research Service. In lieu of establishing a subcommittee, the R&D Committee may obtain these services through an MOU with another VA, with an affiliate institution, or with other sources as allowed by VA policies. Representatives to these "in-lieu-of" committees must be appointed by the Facility Director. The R&D Committee may use agreements or contracts to supply program expertise for research programs.

1.3.2. SRS

The SRS is a subcommittee of the R&D Committee that identifies and manages safety and security risks for the Research Service. The SRS reviews all research activities involving biological, chemical, physical, and/or ionizing and nonionizing radiation hazards prior to submission for funding and must grant approval prior to the start of the project. The SRS reviews and approves Research Protocol Safety Surveys (RPSSs) submitted by Principal Investigators and conducts annual reviews of all active research protocols. The SRS coordinates with other local or affiliated regulatory programs, personnel, or committees, such as the Environment of Care (EOC) Committee, the Radiation Safety Committee, and GEMS Committee. The SRS identifies individual projects that require hazard monitoring and/or medical surveillance for affected personnel and ensures that effective training and safety and health programs are in place. Incident reports are reviewed by the SRS to ensure that appropriate action has been taken.

The SRS addresses the root cause for each deficiency identified during research laboratory inspections and coordinates follow-up evaluations to ensure that effective abatement solutions are implemented. The SRS reviews reports of lost time, injuries and illnesses, and significant adverse environmental events, and reports trends in injuries and illnesses to the R&D Committee as appropriate.

The SRS establishes and annually reviews the Research Chemical Hygiene Plan (CHP) and other research-specific plans as required, including the Research Safety Plan, the Research Security Plan, and the Research Emergency Preparedness Plan. The SRS also ensures that annual drills are conducted to test the effectiveness of each of the plans. The SRS is also responsible for evaluating and mitigating security concerns related to the Research Program.

1.4. Employee Occupational Health (EOH) Services

EOH services are integral to research safety and health programs. Although not a requirement, EOH participation on the SRS can enhance the overall safety program. EOH services include pre-employment physicals, treatment of minor employee injuries, and medical clearance to work with laboratory animals or for the use of a respirator, if required. EOH protocols are available in the VHA Employee Occupational Health Guidebook.

1.5. Research Safety Officials

At some facilities, the Research Service may employ staff dedicated to the oversight of specific safety functions. Research safety officials work in concert with the facility OSH staff but are only responsible for Research Service-level programs. Research safety officials report directly to the Research Service.

- Research Safety Officer: In some of the larger VHA research facilities, the ACOS or CRADO may appoint a Research Safety Officer to manage safety issues associated with research laboratories. The Research Safety Officer position can be full time, part time, or assigned as a collateral duty.

- Research Safety Coordinator (RSC): The R&D Committee appoints an RSC to supervise the operation of the Research Safety Program. Responsibilities of the RSC must be specified in the local written policies of the Research Safety Program.

- Biological Safety Officer (BSO): The R&D Committee may also appoint a BSO if the Research Safety Program has projects meeting hazard levels for rDNA, specifically:

    - The use of rDNA at biosafety level three, or

    - Large scale (greater than 10 liters of culture) research or production activities involving viable organisms that contain rDNA molecules.

- Chemical Hygiene Officer (CHO): A CHO must be appointed by the R&D Committee to serve as a technical expert for development and implementation of the Research CHP.

1.6. Research Compliance Officer (RCO)

The RCO is responsible for reviewing and auditing research projects as specified by ORO. The reviews and audits are conducted to ensure compliance with applicable federal requirements and VHA policies. The RCO may not serve as a member of research review committees but may serve as a non-voting consultant as needed or specified in standard operating procedures (SOPs). RCOs are also responsible for conducting periodic audits of research activities in accordance with VA requirements. The RCO reports directly to the Facility Director. Additional information for RCOs can be found on the ORO Research Compliance and Technical Assistance SharePoint site.

1.7. Principal Investigator

Principal Investigators are accountable for all research activities in their assigned areas, including scientific, management, and administrative duties. Principal Investigators ensure that all research protocols are submitted to the SRS for review using VA Form 10-0398, Research Protocol Safety Survey, or an equivalent local form.

As leaders of research teams, Principal Investigators must ensure that all safety principles and rules of conduct are followed within research laboratory areas. Principal Investigators must set good examples by establishing safe work practices, monitoring compliance, and implementing effective corrective actions. In addition, Principal Investigators must identify research laboratory-specific hazards and provide training on all procedures performed within their area of responsibility, as well as on safety precautions for each research protocol. They must ensure that research laboratory staff is adequately trained, has appropriate scopes of practice, and is competent in the performance of assigned duties. The Principal Investigators are also responsible for the safe use of engineering controls, such as chemical fume hoods and biological safety cabinets (BSCs), and the use of appropriate personal protective equipment (PPE) by research laboratory staff.

Principal Investigators must ensure that a current inventory of all hazardous chemicals is readily available for research laboratory staff. Principal Investigators are responsible for compliance with the Research CHP and for providing access to Safety Data Sheets (SDSs). Principal Investigators must notify the facility Safety Office and the SRS of all occupational injuries or illnesses incurred by staff under their supervision and ensure that all incidents are entered into the agency's accident reporting system.

1.8. Safety Office

The facility Safety Office is primarily responsible for anticipating, recognizing, evaluating, and controlling safety, health, and environmental regulatory issues throughout the facility and for achieving compliance with relevant federal, state, and local regulations. The facility Safety Office interfaces with regulatory enforcement agencies during announced and unannounced inspections. The facility Safety Office coordinates medical surveillance with EOH and ensures assessment of hazardous materials, environmental stressors (chemical, biological, and physical), life safety, environmental compliance, and emergency management concerns within research areas.

The facility Safety Office maintains or has access to occupational safety and health records. The records include inspections and abatement reports, complaints, adverse events, and the appropriate Occupational Safety and Health Administration (OSHA) injury/illness logs. A record of all safety training and attendees should be maintained in the VHA-approved Talent Management System (TMS). Compliance with research safety policies is the responsibility of the Principal Investigator, but the facility Safety Office should help identify unsafe behaviors and conditions and assist Principal Investigators in developing effective solutions. Accident and incident investigation, root-cause analyses, evaluating indoor air quality complaints, exposure monitoring, and respirator fit testing are the combined responsibilities of Research Service and the facility Safety Office.

The GEMS Coordinator may be a member of the facility Safety Office staff and is often responsible for hazardous waste management. GEMS Coordinators

typically oversee management and disposal of waste streams and provide solutions to waste issues in research laboratories.

The Radiation Safety Officer (RSO) may or may not be assigned to the facility Safety Office. The RSO is responsible for all issues pertaining to ionizing radiation safety and disposal of radioactive wastes and, at some facilities, may be the Laser Safety Officer.

1.9. FMS

The Safety Office and FMS work together to maintain a safe and healthful research laboratory environment. Heating, ventilation, and air conditioning (HVAC); plumbing; water supply; gas; sewer; and electrical services are provided by the facility and maintained by FMS. General ventilation is an important part of research laboratory safety because it ensures adequate air flow, appropriate number of air changes, and relative positive/negative room pressure relationships. Further, the correct balance of the room ventilation system is critical to proper functioning of research laboratory fume hoods and exhausted BSCs.

The Office of Construction & Facilities Management (CFM) provides design manuals and specifications for research laboratory spaces and equipment locations. FMS uses this information to ensure optimal work space and functional equipment in the research laboratory. These publications are available in the CFM Technical Information Library (TIL).

1.10. Key Issues

1.10.1. Communication

Good communication between research sites and ORO is important. Adverse events, incidents, and exposures resulting in, or likely to result in, adverse health effects in research laboratories must be reported in compliance with VHA Handbook 1058.01, Research Compliance Reporting Requirements. Items that require reporting include:

- Serious unanticipated problems involving risks to workers or the environment.
- Work-related and other injuries: Any work-related injury to personnel involved in VA research or any research-related injury to any other person that requires more than first aid.
- Work-related exposures: Any work-related exposure of research laboratory staff to pathogens or hazardous materials resulting in health symptoms that require more than minor medical intervention or that could lead to serious complications or death.
- Serious or continuing non-compliance: Any serious or continuing non-compliance with VA or other federal requirements related to research safety.

- Near misses: Voluntary reporting of near misses (an event that could have resulted in an adverse event).

The facility Safety Office must be notified 30 days prior to decommissioning a research laboratory. The notification applies to research laboratory space that is being reassigned, vacated, or converted to non-laboratory use and requires identification, removal, and disposal of hazardous chemicals, radioactive materials, hazardous wastes, and/or equipment. If the facility Safety Office is not notified of the decommissioning of a research laboratory, it is considered non-compliant and is reportable to ORO.

Additional reporting information can be found in VHA Handbook 1058.01.

1.10.2. Without Compensation (WOC) Staff

WOC staff plays a large role in VHA research. Typically, they are academic affiliate personnel performing research on VA property and, at some research laboratories, may comprise up to 75% of the research staff. It is important for WOC staff to be aware that when they use any VHA resource, they are subject to all of the same regulations, requirements, and policies as federal employees. WOC staff is also subject to VHA training requirements, OSHA regulations, and reporting requirements. Some facilities have established an MOU that describes training reciprocity with their academic affiliate.

1.10.3. External Inspections

Officials authorized by the VA, the Secretary of HHS, the Secretary of the USDA, General Accounting Office (GAO), or other authorized federal agencies or entities may conduct inspections of all VHA research laboratories. Such agencies or entities include the Centers for Disease Control and Prevention (CDC), Environmental Protection Agency (EPA), OSHA, VA Office of the Inspector General (OIG), accrediting agencies, ORD, and ORO. Inspections may be either announced or unannounced.

1.11. References and Resources

1. ORD Policies: http://www.research.va.gov/resources/policies/by_number.cfm.
2. VHA Directive 7701, Occupational Safety and Health (OSH).
3. VHA Handbook 7701.01, Occupational Safety and Health (OSH) Program Procedures.
4. VHA Handbook 1058.01, Research Compliance Reporting Requirements.
5. VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories.
6. VHA Handbook 1200.08, Safety of Personnel Engaged in Research.

1.12. Enclosures and Fact Sheets

Fact Sheets for Research Laboratory Guidebook

The following fact sheets contain quick-reference information relevant to this chapter:

1.1 Applicable Regulations
1.2 Applicable VHA Policies
1.3 Research Laboratory Audits and Inspections

Research Laboratory Safety: Risk Assessment

2.1. Introduction

A risk assessment process is necessary for identifying research laboratory hazards and for developing strategies to reduce or eliminate occupational accidents, injuries, and illnesses. Management of research laboratory risk is challenging because it entails the application of standard risk assessment tools to complex research laboratory processes. The following chapter reviews specific analyses, monitoring, and testing methods that have been proven to yield reliable estimates of the risks associated with research laboratory equipment, procedures, and protocols.

Personnel following the guidance in this chapter are expected to have a basic understanding of safety and industrial hygiene principles. A comprehensive discussion of industrial hygiene equipment and sampling can be found in the VHA Industrial Hygiene Guidebook. A series of reference materials for many of the topics in this chapter are also available online from the American Industrial Hygiene Association (AIHA).

2.2. Job Hazard Analysis (JHA)

Many hazards are associated with research laboratories. Conducting a JHA helps to identify inherent hazards and adequately control risks by implementing effective control measures and work practices. A JHA involves information gathering, process review, and fault/risk analysis. The JHA can provide the information needed to reduce incidents of injuries and illnesses, implement appropriate engineering and administrative controls, develop more effective work practices, and select proper personal protective equipment (PPE). Additional benefits include reducing costs associated with workers' compensation claims and increasing productivity. The basics of JHA are reviewed in the following publications:

- Occupational Safety and Health Administration (OSHA) Publication 3071, Job Hazard Analysis.
- Department of Energy (DOE) JHA Help Center.

2.2.1. Frequency

The JHA is an effective tool that can assist in preventing accidents and over-exposure when information is accurate and current. A JHA should be performed or re-evaluated when there is a new job introduced; when a process or equipment changes; and/or when an illness, injury, or near-miss is reported. JHAs should be reviewed and revised periodically to ensure accuracy and completeness.

2.2.2. Process

The JHA process focuses on the relationships between the employee, the task, the tools, and the work environment. Many tasks are performed within research laboratories, and each task has hazards that can be analyzed. JHAs can also be used to develop research laboratory procedures and to integrate safety into the performance of research-related tasks. Common tasks include, but are not limited to, sample collection, specimen manipulation, sterilization, glass washing, solution preparation, solution transfers, material transportation, and waste disposal. All steps from preparation to disposal or transfer should be reviewed.

The following steps are generally included in the JHA process:

- Identify a task to be performed during the JHA.
- Review records, standard operating procedures, instructions, and previous JHAs.
- Observe, identify, and analyze the hazards of each task or process.
- Determine controls to eliminate or mitigate the hazards identified.
- Implement the controls and determine their adequacy.
- Review the JHAs periodically and update to address process changes.

When all of the observation data has been compiled, the summary should be reviewed with research laboratory staff to determine if any aspects were overlooked. At a minimum, documentation should include:

- Task name and location.
- Personnel affected.
- Potential issues and exposures.
- Hazard consequences/severity if it occurs, contributing factors, and triggers.
- Probability of the hazard occurring.
- Controls to prevent, minimize, or eliminate the hazard.

The JHA process includes developing controls to mitigate the associated risk by eliminating or reducing exposure to existing hazards; substituting the hazardous task with a task that is deemed less hazardous; or minimizing the hazard from the task by implementing engineering controls, administrative controls, work practices, or wearing PPE. Enclosures 2-1 through 2-4 (listed on the RLS Guidebook webpage) provide examples of typical research laboratory JHAs, including the handling, transporting, and storing of cryogens; use and maintenance of electrical research laboratory equipment; the preparation of samples for analysis; and gel electrophoresis.

2.3. Dermal Exposure Risk Assessment

Dermal exposure risk assessment is more difficult to quantify than assessing the risks of ingestion or inhalation of chemicals. OSHA, National Institute of Occupational Safety and Health (NIOSH), and the American Conference of

Governmental Industrial Hygienists (ACGIH®) use “skin” notations to denote that dermal exposure significantly contributes to the total body burden/dose for select chemicals. However, dose-response information for dermal exposures is not available for many chemicals. Additional information on dermal exposures can be found on the OSHA Dermal Exposure website and the NIOSH Skin Exposures & Effects website. See Enclosure 2-5 for detailed information regarding dermal exposure risk assessment and sampling.

2.4. Inhalation Exposure Risk Assessment

Research laboratory chemical inhalation exposures are typically below regulatory limits due to small-quantity chemical transfers and ventilation controls. However, the toxicity and interaction of some highly toxic chemicals (such as carcinogens, mutagens, and reproductive toxins) and sensitizers used in research laboratories warrants conducting a negative exposure assessment. A negative exposure assessment rules out exposures above regulatory thresholds to characterize and document work-related exposures.

Personal air sampling is the preferred method used to evaluate worker exposures to airborne contaminants. Personal air sampling is conducted using active and/or passive sampling methods. Active sampling uses an air pump to draw a known volume of air through collection media, while passive sampling uses the natural movement of air across a membrane by diffusion to collect samples. In both cases, the air sample is obtained from within the employee’s breathing zone.

2.5. Sampling Strategies

2.5.1. Control Banding

Modern control banding is a risk management process designed to protect workers against hazardous chemical exposures. According to the CDC, control banding is a generic technique that determines a range or “band” of hazards and exposures. Control banding groups chemicals based on physical and chemical characteristics, how the chemical will be handled or processed, and the anticipated exposure. The process of control banding supports assessment of the working environment and the development of reasonable methods of control for potential exposures. Detailed information on developing a control banding model can be found in Enclosure 2-6.

2.5.2. Similarly Exposed Groups (SEGs)

The SEG approach relies on grouping workers on the basis of similarity of work, hazardous agents, and environmental characteristics. Such a comprehensive exposure assessment strategy characterizes exposure variability and provides data for baseline monitoring, surveillance, and exposure control measures. While there is general agreement on the concept of SEGs, there are limitations on its use. Detailed information on SEGs is provided in Enclosure 2-7.

2.6. Air Sampling/Monitoring

The investigation and characterization of airborne contaminants is the cornerstone of an industrial hygiene exposure evaluation and is accomplished through air sampling using traditional “pump and tube” or passive badge methods, or through air monitoring using portable, direct-reading instruments. However, no matter how carefully planned or effectively executed, a single air sampling or monitoring event is no more than a snapshot in time. Accordingly, critical exposure sampling and/or monitoring must be repeated several times to account for random or systematic variation and to produce a more statistically reliable exposure profile. Confidence limits are also calculated to determine the probability of compliance with regulatory exposure limits.

Exposure characterization should be specific enough to ensure that subsequent assessments are evaluating the same or substantially similar tasks, chemical manipulations, and environmental conditions, in order to constitute a homogenous exposure group. Gathering information for characterizing the exposures should include:

- What are the chemical, physical, and/or biological agents in the workplace?
- What are the potential sources and pathways of exposure?
- Who is exposed, what is the duration of exposure, and what are their job duties?
- What engineering controls, administrative controls, and PPE are in place?

Sampling plans based on the exposure characterization must also be developed and used to identify employees with similar exposures. The objectives of an exposure sampling plan are:

- Collect exposure data to monitor effectiveness of exposure controls.
- Collect additional data to improve accuracy and establish precision of exposure estimate.
- Comply with periodic monitoring required by regulatory agencies.

For information regarding collecting air samples, including sample location, collection methods, analysis, and documentation, refer to the VHA Industrial Hygiene Guidebook.

Prior to sampling, some important considerations and decisions must be made by Research Service with input from an Industrial Hygienist, including:

- Prioritization based on risk assessments.
- Sample method/media.
- Length of sampling interval.
- Scheduling of sampling to ensure capture of highest exposure risk.

2.7. References and Resources

1. CDC and NIOSH (2005). *FAQs about control banding*: http://www.cdc.gov/niosh/topics/ctrlbanding/ctrlbandingfaq.html.

2. CDC and NIOSH (2009). *Qualitative risk characterization and management of occupational hazards*: *Control banding*. Publication Number 2009-152: http://www.cdc.gov/niosh/docs/2009-152/pdfs/2009-152.pdf.

3. NIOSH, Occupational Exposure Sampling Strategy Manual.

4. OSHA Technical Manual, Personal Sampling for Air Contaminants.

2.8. Enclosures

Enclosure 2-1 Sample Job Hazard Analysis: Handling, Transporting, and Storing Cryogens

Enclosure 2-2 Sample Job Hazard Analysis: Use and Maintenance of Electrical Laboratory Equipment

Enclosure 2-3 Sample Job Hazard Analysis: Preparing Samples for Analysis

Enclosure 2-4 Sample Gel Electrophoresis Job Hazard Analysis

Enclosure 2-5 Dermal Exposure Risk Assessment

Enclosure 2-6 Developing a Control Banding Model

Enclosure 2-7 Similarly Exposed Groups (SEGs)

Hazard Communication

3.1. Introduction

Code of Federal Regulations (CFR) 29 CFR 1910.1200, Hazard Communication is based on the idea that employees have both a need and a right to know the identities and hazards of the chemicals in the work environment. Employees also need to know what engineering controls, work practices, and personal protective equipment (PPE) are needed to minimize or eliminate exposures, substitute less hazardous materials, and establish proper work practices. This should reduce the occurrence of work-related illnesses and injuries caused by chemical exposures.

The Research Chemical Hygiene Plan (CHP) provides safety guidance to researchers and incorporates components of the Hazard Communication Standard (HCS). The HCS requires that the Research CHP incorporates changes to methods of communicating hazards through manufacturer labeling, Safety Data Sheets (SDSs), and employee training. The 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories requires manufacturer's labels on incoming chemicals to not be removed or defaced. Guidelines for labeling of secondary containers must be prescribed in the Research CHP. Research laboratory staff is required to be trained on the local labeling system, HCS manufacturer label information, and SDS format and content.

The Research CHP must include provisions for employees from non-research areas who work in or may need access to the research laboratory (for example, housekeepers or engineering staff). These employees are trained under the local Hazard Communication Program (HCP), but should also be advised of hazards in the research laboratory prior to being allowed access to research areas.

Detailed information about the Research CHP and guidelines for creating a Research CHP can be found in Chapter 4, Management of Hazardous Chemicals in Research Laboratories.

3.2. Discussion

The HCS evolved in the mid-1980s after a disastrous chemical leak in Bhopal, India and after many states developed right-to-know laws. The standard was designed to protect employees by ensuring that they are aware of the hazards of the chemicals they work with. The Veterans Health Administration (VHA) requires all facilities to comply with Occupational Safety and Health Administration (OSHA) regulations, and the HCS requires a site-specific written HCP that details how they will comply with the standard. VHA adopted the Globally Harmonized System (GHS), which was incorporated into the HCS on March 26, 2012. VHA also adheres to specific requirements that have been negotiated by the collective bargaining units. The requirements can be viewed on the VHA Center for Healthcare Environment and Facilities Programs (HEFP) website under the Safety Management Program page.

The HCS benefits employees by reducing confusion in the workplace, facilitating safety training, and improving understanding of chemical hazards. The HCS requires the classification of chemicals according to health and physical hazards and establishes consistent labels and SDSs for all chemicals made in the United States or imported from abroad.

3.3. The HCS

The VHA Industrial Hygiene Guidebook provides a detailed discussion of facility responsibilities and hazard communication. Additional information and potential compliance issues can be found in Chapter 10, Hazard Communication Standard, of the VHA Industrial Hygiene Guidebook.

The HCS provides a process for evaluating chemicals and ensuring that hazards are communicated to employees. Required methods for communicating hazards include a written HCP, labels and warnings, SDS, and information and training. This information is usually captured in the Research CHP. A written HCP is required and will include labelling, training, and use of SDSs in the workplace.

It is commonly believed that a manufacturer will never release trade secrets, but there are some conditions under which hazard information pertaining to trade secrets must be provided. For example, this would pertain to VHA research laboratory-manufactured chemicals with proprietary formulations. Section (i)(2) of the HCS states that when “a treating physician or nurse determines that a medical emergency exists and the specific chemical identity and/or specific percentage of composition of a hazardous chemical is necessary for emergency or first-aid treatment, the chemical manufacturer, importer, or employer shall immediately disclose the specific chemical identity or percentage composition of a trade secret chemical to that treating physician or nurse, regardless of the existence of a written statement of need or a confidentiality agreement.” However, the chemical manufacturer or importer may require the medical professional to sign a confidentiality agreement as soon as circumstances permit. For example, investigational drug exemptions (IDEs) may include proprietary information that is not readily available unless requested. Appendix E, Definition of “Trade Secret” (Mandatory), of the HCS contains the accepted definition of trade secret and is accessible online at: http://www.osha.gov/dsg/hazcom/appendix_e.pdf.

3.4. Criteria for Classification of Chemical Hazards

The HCS provides specific criteria for classifying health and physical hazards. It requires manufacturers to follow specific criteria to assign their products to a hazard class and to include harmonized words and pictograms on their SDSs and labels. Detailed information on HCS guidelines for mixture classification is available online at: http://www.osha.gov/dsg/hazcom/global.html.

3.4.1. Health Hazards

The HCS has defined ten specific health hazard classes and may have multiple categories and subcategories within a class. The criteria for determining whether

or not a chemical is classified as a health hazard are detailed in Appendix A, Health Hazard Criteria, of the HCS.

The HCS defines health hazard as a chemical that is classified as posing one of the following hazardous effects:

- Acute toxicity (any route of exposure).
- Skin corrosion or irritation.
- Serious eye damage or eye irritation.
- Respiratory or skin sensitization.
- Germ cell mutagenicity.
- Carcinogenicity.
- Reproductive toxicity.
- Specific target organ toxicity (single or repeated exposure).
- Aspiration hazard.

3.4.1.a. Acute Toxicity

The toxicity categories are based on the chemical's lethal dose 50 (LD_{50}) and lethal concentration 50 (LC_{50}). The "50" refers to the percent of the test population that is adversely affected. A Category 1 chemical is of the greatest concern because only a small exposure presents a severe hazard, whereas a Category 4 chemical requires a much higher degree of exposure for a lethal effect. The HCS also provides category guidance for oral, dermal, and inhalation exposure.

3.4.1.b. Skin Corrosion or Irritant

A *corrosive* is a substance that destroys skin tissue, namely visible necrosis through the epidermis and into the dermis. It is based on animal testing, although the HCS does not identify the animal type or weight. It does specify the length of observation. Corrosion is divided into two categories: Corrosive and Irritant.

- Category 1 (Corrosive) has three subcategories: 1A includes concentrated acids or concentrated bases and causes the greatest damage, 1B, and 1C causes the least amount of damage. The subcategories are based on length of exposure and observation time. For detailed subcategory information, see Appendix A of the HCS.

- Category 2 (Irritant) is a single irritant category with descriptive criteria for redness, eschar, swelling, and inflammation. The effect of irritants is reversible.

3.4.1.c. Serious Eye Damage or Eye Irritation

The HCS has two categories of eye hazards: Category 1 is Irreversible eye effects. *Serious eye damage* is defined in the HCS as "tissue damage in the eye or serious physical decay of vision".

Several factors are considered in determining the serious eye damage or eye irritation potential:

- Accumulated human and animal experiments.
- Structure activity or structure property relationship to a substance or mixture already classified.
- pH extremes that may produce serious eye damage.

Category 2 of eye hazards is reversible eye effects (irritation), with two subcategories (2A and 2B) depending on the duration of the exposure effects. Eye irritation means changes in the eye that are fully reversible within 21 days of application of the chemical.

3.4.1.d. Respiratory or Skin Sensitization

The HCS considers effects on both the respiratory system and/or the skin. Sensitizers are in a single category, further divided into two subcategories based on the frequency of occurrence. For detailed subcategory information, see Appendix A of the HCS.

3.4.1.e. Germ Cell Mutagenicity

The HCS defines a mutation as “a permanent change in the amount or structure of the genetic material in a cell”. The term *mutation* applies both to inherited genetic changes and to the underlying DNA modifications. The terms *mutagenic* and *mutagen* are used for agents that give rise to an increased occurrence of mutations in populations of cells and/or organisms. The HCS further states that “the terms *genotoxic* and *genotoxicity* apply to agents or processes that alter the structure, information content, or segregation of DNA, including those that cause DNA damage by interfering with normal replication processes”. Genotoxicity test results are usually taken as indicators for mutagenic effects. The HCS states: “This hazard class is primarily concerned with chemicals that may cause mutations in the germ cells of humans that can be transmitted to the progeny.” The population at risk is any person of child bearing age. The HCS uses two categories of mutagenicity with subcategories including:

- Category 1, as defined in Appendix A of the HCS: “Substances known to induce heritable mutations or to be regarded as if they induce heritable mutations in the germ cells of humans”.

- Category 1A includes compounds that are known heritable mutations found in germ cells of human populations.

- Category 1B includes compounds regarded as if they induce heritable mutations in germ cells of human populations.

- Category 2 includes, as defined in Appendix A of the HCS: “Substances which cause concern for humans owing to the possibility that they may induce heritable mutations in the germ cells of humans.”

3.4.1.f. Carcinogenicity

A carcinogen is defined as a substance that induces or increases the incidence of cancer. According to Appendix A of the HCS, “substances and mixtures which have induced benign and malignant tumors in well-performed experimental studies on animals are considered also to be presumed or suspected human carcinogens unless there is strong evidence that the mechanism of tumor formation is not relevant for humans”. The HCS further states: “Classification of a substance or mixture as a carcinogenic hazard is based on inherent properties and does not provide information on the level of the human cancer risk”. The two main categories of carcinogens include known or presumed carcinogens (Category 1) and suspected carcinogens (Category 2). Category 1 carcinogens are further distinguished on the basis of whether the evidence for classification is largely from human data (Category 1A) or from animal data (Category 1B).

3.4.1.g. Reproductive Toxicity

The HCS places reproductive toxins in a separate class of toxins. A *reproductive toxin* is defined as a chemical that affects reproductive capabilities, including chromosomal damage (mutations), effects on the fetus (teratogenesis), and developmental toxicity. Symptoms may include birth defects and sterility. The HCS classifies reproductive toxicity in one of two categories:

- Category 1 chemicals have effects on sexual function, fertility, and development. There are two subcategories:
    - Category 1A chemicals are known human reproductive toxicants.
    - Category 1B chemicals are presumed human reproductive toxicants.
- Category 2 chemicals are suspected reproductive toxicants.

3.4.1.h. Specific Target Organ Toxicity (Single or Repeated Exposure) STOT-SE

In the HCS, a single exposure affecting a target organ is classified as STOT-SE. It means there is specific, non-lethal target organ toxicity arising from a single exposure to a chemical (acute). There are three categories for single exposures:

- Category 1 STOT-SE substances include those that can produce significant toxicity in humans following a single exposure.
- Category 2 STOT-SE substances include those that can be presumed to have the potential to be harmful to human health following single exposure.
- Category 3 STOT-SE applies to substances that have target organ effects but that do not meet the criteria to be classified in Categories 1 or 2.

STOT-RE

STOT-RE means specific target organ toxicity arising from repeated exposure to a substance or mixture (chronic). STOT-RE has two categories.

- Category 1 STOT-RE substances are those that have produced significant toxicity in humans following repeated or prolonged exposure.
- Category 2 STOT-RE substances are those that can be presumed to have the potential to be harmful to human health following repeated or prolonged exposure based on evidence from studies in experimental animals.

3.4.1.i. Aspiration Hazard

An *aspiration hazard* is defined in the HCS Appendix A as "the entry of a liquid or solid chemical directly through the oral or nasal cavity, or indirectly from vomiting into the trachea and lower respiratory system. Aspiration toxicity includes severe acute effects such as chemical pneumonia, varying degrees of pulmonary injury, or death following aspiration. Aspiration is initiated at the moment of inspiration, in the time required to take one breath, as the causative material lodges at the upper respiratory and digestive tracts". Chemicals known to cause human aspiration toxicity hazards or that are to be regarded as if they cause human aspiration toxicity hazards is the only category of aspiration hazards.

3.4.2. Physical Hazards

The HCS defines 16 physical hazard classes that may have a category, group, or type within the class. The exact wording and detailed information of the HCS Physical Hazards is found in the HCS Appendix B, Physical Criteria (Mandatory).

3.4.2.a. Explosives

As stated in Appendix B of the HCS: "An *explosive chemical* is a solid or liquid chemical which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. Pyrotechnic chemicals are included even when they do not evolve gases." Explosive materials such as nitroglycerin and picric acid present unique storage and handling concerns. 29 CFR 1910.109, Explosives and Blasting Agents has clearly defined regulations. Trinitrotoluene and nitroglycerine are examples of an explosive.

3.4.2.b. Flammable Gases

The HCS defines *flammable gas* as "a gas having a flammable range with air of 20°C (68°F) and a standard pressure of 101.3 kPa (14.7 psi)". There are two categories of flammable gases based on the ratio of gas and air. Flammable aerosols are in a separate class. The HCS notes that: "Flammability shall be determined by tests or by calculation in accordance with ISO 10156 (incorporated by reference; See §1910.6). Where insufficient data are available to use this method, equivalent validated methods may be used". International Organization

for Standardization (ISO) 10156:2010, Gases and Gas Mixtures--Determination of Fire Potential and Oxidizing Ability for the Selection of Cylinder Valve Outlets, can be found online at: http://www.iso.org/iso/catalogue_detail.htm?csnumber=44817. Propane and natural gas are examples of flammable gas.

3.4.2.c. Flammable Aerosols

According to the HCS Appendix B: "Aerosol means any non-refillable receptacle containing a gas compressed, liquefied or dissolved under pressure, and fitted with a release device allowing the contents to be ejected as particles in suspension in a gas, or as a foam, paste, powder, liquid or gas." For practical purposes, this includes compounds dispersed from a pressurized spray can, such as paint or adhesives. A flammable aerosol is classified in one of two categories based on percentage of flammable components. Spray adhesives are examples of flammable aerosols.

3.4.2.d. Flammable Solids

The HCS defines a *flammable solid* as "a solid which is a readily combustible solid, or which may cause or contribute to fire through friction. Readily combustible solids are powdered, granular, or pasty chemicals which are dangerous if they can be easily ignited by brief contact with an ignition source, such as a burning match, and if the flame spreads rapidly". Examples include magnesium, powdered aluminum, and paraformaldehyde. The two flammable solids categories are based on the Burning Rate Test as described in Appendix B of the HCS.

3.4.2.e. Oxidizing Gases

The HCS distinguishes oxidizers as three separate classes: gases, liquids, and solids.

An oxidizing gas may cause or contribute to the combustion of other material more than air does. There is only one category in this class. Oxygen is the most common example of an oxidizing gas.

3.4.2.f. Oxidizing Liquids

An *oxidizing liquid*, while not necessarily combustible, may cause or contribute to the combustion of other materials. The contributing factor is oxygen yield. There are three categories of oxidizing liquids based on the results of an oxygen yield test. Concentrated bleach and hydrogen peroxide are examples of oxidizing liquids.

3.4.2.g. Oxidizing Solids

An oxidizing solid is defined in the HCS as "a solid which, while in itself not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material". Oxidizing solids are divided into three categories based on the results of an oxygen yield test. Potassium permanganate and ammonium persulfate are two examples of oxidizing solids.

3.4.2.h. Gases Under Pressure

The HCS refers to *gases under pressure* and defines them as “gases that are contained in a receptacle at a pressure of >200 kPa (29 psi) or that are liquefied or refrigerated”. They are divided into four groups including: compressed gases, liquefied gases, dissolved gases, and refrigerated liquefied gases. An example of refrigerated liquefied (cryogenic) gas is liquid nitrogen.

3.4.2.i. Flammable Liquids

Under the HCS, the term *combustible liquid* was eliminated and those liquids have been incorporated into the flammable liquid class. A flammable liquid is defined as having a flash point of not more than 93°C (199.4°F). According to the HCS, “a flammable liquid shall be classified in one of four categories in accordance with Table B.6.1” (pictured below). Ethanol and acetone are examples of flammable liquids.

TABLE B.6.1—CRITERIA FOR FLAMMABLE LIQUIDS

Category	Criteria
1	Flash point < 23°C (73.4°F) and initial boiling point ≤ 35°C (95°F)
2	Flash point < 23°C (73.4°F) and initial boiling point > 35°C (95°F)
3	Flash point ≥ 23°C (73.4°F) and ≤ 60°C (140°F)
4	Flash point > 60°C (140°F) and ≤ 93°C (199.4°F)

Figure 3-1: Table B.6.1 from 29 CFR 1910.1200, Appendix B

3.4.2.j. Self-Reactive Chemicals

The HCS refers to *self-reactive* chemicals or “thermally unstable liquid or solid chemicals exhibiting a strong exothermic decomposition without oxygen”. This definition excludes chemicals classified as explosives, organic peroxides, oxidizing liquids, or oxidizing solids.

The HCS explains: “A self-reactive chemical is regarded as having explosive properties when in laboratory testing the formulation is liable to detonate, to deflagrate rapidly, or to show a violent effect when heated under confinement.” Self-reactive chemicals shall be classified into seven categories (Type A to G). Category placement depends on the chemical’s ability to self- detonate (initiate explosion) and the speed of deflagration (rapid burning). Category parameters are found in Appendix B of the HCS. Ammonium perchlorate is an example of a self-reactive chemical.

3.4.2.k. Pyrophoric Liquids

The HCS divides pyrophorics in two classes (liquid and solid), and defines different test criteria. In the HCS, *pyrophoric liquid* means “a liquid which, even in

small quantities, is liable to ignite within 5 minutes after coming into contact with air". There is a single category for this class based on testing results using the fourth edition UN Manual of Tests and Criteria. If a liquid is known to be stable at room temperature for prolonged periods of time, the classification procedure for pyrophoric liquids does not need to be applied. Examples of pyrophoric liquids include t-butyl lithium and silane.

3.4.2.l. Pyrophoric Solids

Pyrophoric solids are classified according to the same criteria as pyrophoric liquids. Lithium aluminum hydride and other alkali metal aluminum hydride are examples of pyrophoric solids.

3.4.2.m. Self-Heating Chemicals

Self-heating chemicals is a new class in the HCS. It is defined as "a solid or liquid chemical, other than a pyrophoric solid or liquid, which, by reaction with air and without energy supply, is liable to self-heat; this chemical differs from a pyrophoric liquid or solid in that it will ignite only when in large amounts (kilograms) and after long periods of time (hours or days)". Self-heating chemicals fall into one of two categories based on the results of a bulk powder screening test or the Grewer Oven test. Benzoyl peroxide is an example of a self-heating chemical.

3.4.2.n. Chemicals That Emit Flammable Gases When in Contact With Water

The HCS defines water reactive as "*chemicals, which, in contact with water, emit flammable gases*". These solid or liquid chemicals "by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities," according to the HCS. Three categories, based on the evolution of flammable gases, are specified for this class. Sodium metal is an example of a chemical, which, in contact with water, emits flammable gases.

3.4.2.o. Organic Peroxides

The HCS specifies a test method and addresses mixtures for organic peroxides.

According to Appendix B of the HCS:

> Organic peroxide means a liquid or solid organic chemical which contains the bivalent -0-0- structure and as such is considered a derivative of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals. The term organic peroxide includes organic peroxide mixtures containing at least one organic peroxide. Organic peroxides are thermally unstable chemicals, which may undergo exothermic self-accelerating decomposition. In addition, they may have one or more of the following properties:
>
> (a) Be liable to explosive decomposition;
>
> (b) Burn rapidly;
>
> (c) Be sensitive to impact or friction;

(d) React dangerously with other substances.

An organic peroxide is regarded as possessing explosive properties when in laboratory testing the formulation is liable to detonate, to deflagrate rapidly or to show a violent effect when heated under confinement.

3.4.2.p. Corrosive to Metals

In the HCS a chemical that is corrosive to metals is a class of chemical that will materially damage or even destroy metals. A chemical that is corrosive to metals is in a single category based on a corrosion rate test on steel and/or aluminum. Some strong mineral acids, such as nitric acid and sulfuric acid, can be in the corrosive to metals class.

3.5. Warning Signs and Labels

In the HCS, only the signal words *Warning* and *Danger* are acceptable, and the term C*aution* has been eliminated. Chemical manufacturers and importers are required to provide a label that includes a harmonized signal word, pictogram, precautionary statements, and hazard statement for each hazard class and category. Appendix C, Allocation of Label Elements (Mandatory) of the HCS indicates the specific information to be provided for each hazard class and category once a chemical is classified.

While the UN GHS uses nine pictograms to convey the health, physical, and environmental hazards; the HCS uses only eight of these pictograms (Figure 3-2). The HCS does not use the environmental pictogram because environmental hazards are not within OSHA's jurisdiction.

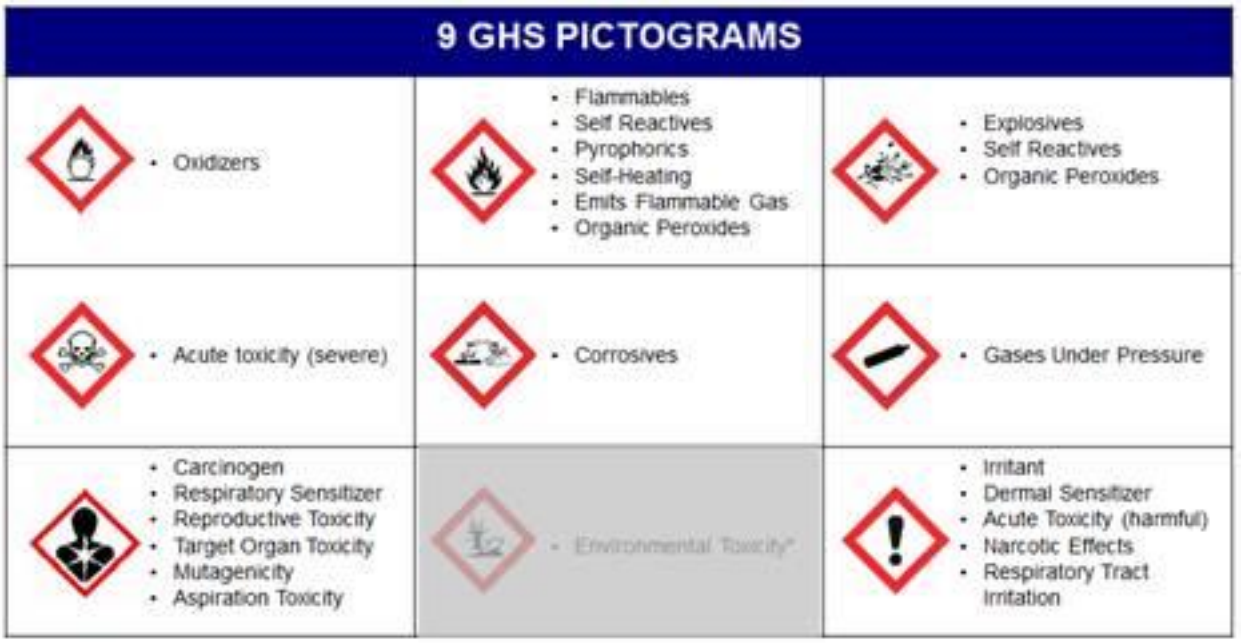

Figure 3-2: Acceptable Pictograms and Hazard Classes for the HCS (Source: OSHA, 2009: http://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf)

3.5.1. Labeling Example

Figure 3-3 is an example of a label based on the HCS for the fictional product ToxiFlam, with a flash point of 48.8°C (120°F) and an oral LD_{50} of 275 milligrams per kilogram (mg/kg).

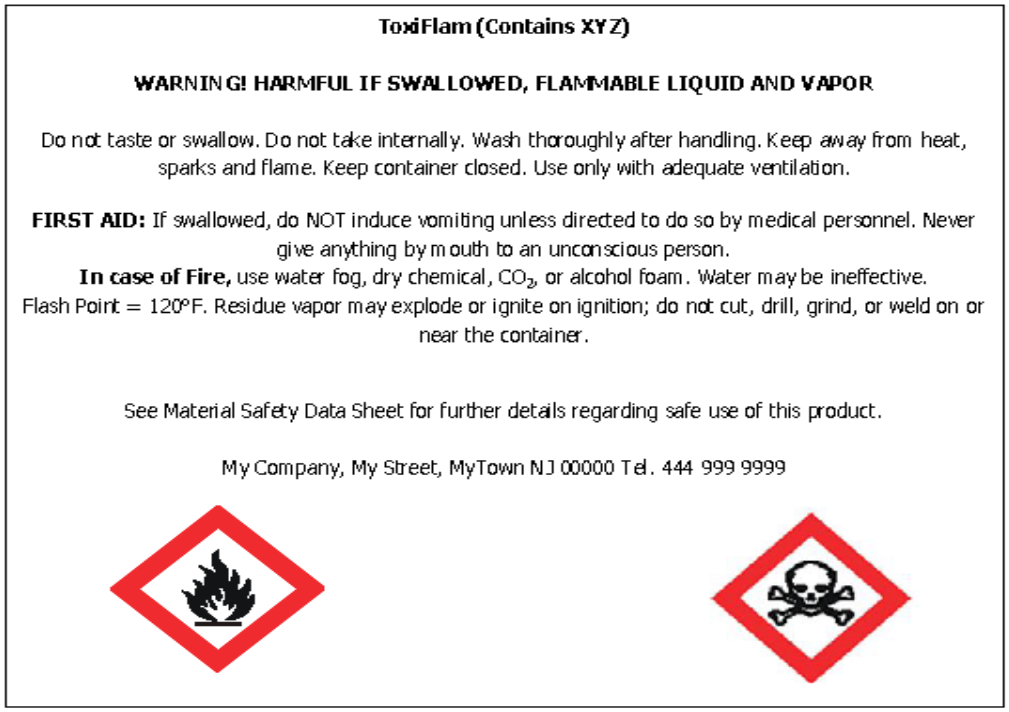

Figure 3-3: Precautionary Label Sample from ANSI Z129.1, Hazardous Workplace Chemicals - Hazard Evaluation and Safety Data Sheet and Precautionary Labeling Preparation (Source: OSHA, 2009)

3.5.2. Additional Requirements

For hazardous products being transported, DOT, FAA, and International Air Transportation Association (IATA) have specific requirements for shipping labels. Outer containers should have required label elements, product identifiers, and hazard symbols. Transportation requirements are in addition to workplace or end-use label requirements. Any employee responsible for labeling a container for packaging, shipping, or receiving must have DOT, FAA, and IATA training for shipping hazardous materials (including initial and refresher training).

3.6. SDS Format

The UN GHS standardizes the section headings, content, and order of information for Safety Data Sheets. Signal word (*Warning* or *Danger*), hazard statements, symbols, and precautionary statements consistent with the UN GHS classification are required on the SDS.

The HCS includes Appendix D, Safety Data Sheets (Mandatory), which identifies information to be included under each section heading. The section headings are:

- Section 1: Identification.
- Section 2: Hazard(s) identification.
- Section 3: Composition/information on ingredients.
- Section 4: First-aid measures.
- Section 5: Fire-fighting measures.
- Section 6: Accidental release measures.
- Section 7: Handling and storage.
- Section 8: Exposure controls/personal protection.
- Section 9: Physical and chemical properties.
- Section 10: Stability and reactivity.
- Section 11: Toxicological information.
- Section 12: Ecological information.
- Section 13: Disposal considerations.
- Section 14: Transport information.
- Section 15: Regulatory information.
- Section 16: Other information, including date of preparation or last revision.

To be consistent with the UN GHS, the SDS includes headers for Sections 12-15, but OSHA will not be enforcing information requirements.

The employer must maintain workplace copies of the required SDSs for each hazardous chemical. The SDSs must be readily accessible to employees during each work shift when they are in their work area. Electronic access, microfiche, and other alternatives to maintaining paper copies of the SDSs are permitted only when there are no barriers to immediate access. If employees travel between workplaces, the SDSs may be kept at the primary workplace facility. However, the employer must ensure that employees can immediately obtain the required information in an emergency. Although the HCS allows electronic copies of the SDS, a VA Union Master Agreement requires one hard copy to be maintained at the facility.

Detailed information regarding SDSs, SDS inventory management, and waste manifests can be found in the VHA Safety Data Sheet/Chemical Inventory Service Guidebook.

3.7. Training

For the research laboratory, employee information and training is an important element of any safety program. The HCS states that: “Employers shall provide employees with effective information and training on hazardous chemicals in their work area at the time of their initial assignment, and whenever a new chemical hazard the employees have not previously been trained about is introduced into their work area.”

The requirement for training is defined in the HCS and applies to research laboratory employees. Training must be designed to ensure that employees:

- Understand health and physical hazard terminology.
- Recognize pictograms.
- Locate SDSs.
- Read and understand SDSs.
- Know the location of the written Research CHP and/or hazard communication plan.

The HCS also requires an "explanation of the labels received on shipped containers and the workplace labeling system used by their employer…" This means that research laboratory staff must be trained to understand the labeling system and the local system that is used to label secondary containers in the research laboratory, as outlined in the Research CHP.

3.8. References and Resources

1. 16 CFR 1500.42, Test for Eye Irritants.
2. 29 CFR 1910.109, Explosives and Blasting Agents.
3. 29 CFR 1910.1200, Hazard Communication.
4. ANSI Z129.1, Hazardous Workplace Chemicals - Hazard Evaluation and Safety Data Sheet and Precautionary Labeling Preparation.
5. ISO 10156:1996, Gases and Gas Mixtures--Determination of Fire Potential and Oxidizing Ability for the Selection of Cylinder Valve Outlets.
6. OSHA, A Guide to the Globally Harmonized System of Classification and Labeling of Chemicals (GHS).
7. United Nations Economic Commission for Europe (2008). UN Manual of Tests and Criteria, 4th ed.: http://www.unece.org/trans/danger/publi/manual/rev4/manrev4-files_e.html.
8. VHA Industrial Hygiene Guidebook.

3.9. Enclosures and Fact Sheets

Fact Sheets for Research Laboratory Guidebook

The following fact sheets contain quick-reference information relevant to this chapter:

3.1 Hazard Communication for Research Laboratories

Management of Hazardous Chemicals in Research Laboratories

4.1. Introduction

This chapter is intended to help familiarize Veterans Health Administration (VHA) research laboratory staff with chemical hazards and to provide a foundation for how to manage hazardous chemicals in a safe and effective manner. The basis for a good research laboratory safety program is an effective Research Chemical Hygiene Plan (CHP), which outlines identification, labeling, handling, storage, and management of chemicals and ready access to Safety Data Sheets (SDS). The Research CHP is mandated by 29 Code of Federal Regulations (CFR) 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories.

According to 29 CFR 1910.1450, manufacturer's labels of incoming chemicals are not to be removed or defaced. Research laboratory staff is required to be trained on the local labeling system for secondary containers, manufacturer label information, and SDS format and content as covered in Chapter 3, Hazard Communication. Employees from non-research areas who work in, or who may need access to the research laboratory, should be advised of hazards identified in the Research CHP prior to being allowed access to research areas.

4.2. Research CHP: Mandatory for Chemical Safety and Health

A Research CHP, as regulated by 29 CFR 1910.1450 and VHA Handbook 1200.08, Safety of Personnel Engaged in Research,outlines the management protocol for research laboratory chemicals. *Note: VHA Handbook 1200.08 is currently being reviewed; this guidebook will be updated to reflect handbook changes upon completion.*

As stated in 29 CFR 1910.1450, the Research CHP "sets forth procedures, equipment, personal protective equipment and work practices that are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace…" The plan must be readily available to all employees and employee representatives, and a copy must be provided to Occupational Safety and Health Administration (OSHA) upon request.

Additional OSHA requirements for the Research CHP include:

- The plan must include procedures for procurement of hazardous chemicals used in research. For VHA research activities, the Subcommittee on Research Safety (SRS) is responsible for reviewing

proposed research involving hazardous chemicals to ensure that the least hazardous chemical is used.

- The following elements must be in place, along with specific measures that the employer will take to ensure research laboratory staff protection:
    - Standard operating procedures (SOPs) relevant and specific to chemical hazards in the research laboratory.
    - Criteria the employer will use to determine and implement control measures to reduce employee exposure to chemicals in the research laboratory.
    - Description of the engineering controls, administrative controls, and personal protective equipment (PPE) used to minimize exposure to chemicals in the research laboratory.
    - Requirements for appropriate PPE selection and maintenance.
- Provisions for employee training, such as annual review of the Research CHP, proper use of chemical fume hoods, and use of PPE.
- Hazard communication (as required), SDS, and labeling protocol must be in place. Hazard communication is discussed in detail in Chapter 3, Hazard Communication.
- Medical program that includes medical surveillance as required by regulations, routine surveillance in accordance with local policies, and first aid.
- Designation of personnel responsible for Research CHP implementation, including assignment, in writing, of a Research Chemical Hygiene Officer (RCHO), who must be an ex-officio, voting member of the SRS.
- Written SOPs for work with particularly hazardous substances (such as select carcinogens, reproductive toxins, and substances with a high degree of acute toxicity) must be established, including:
    - Establishment of a designated area (the entire research laboratory; a defined area within the research laboratory; or devices, such as fume hoods or biological safety cabinets) and rationale used for their selection.
    - Use of PPE and containment devices, such as fume hoods and glove boxes.
    - Procedures for removal and management of hazardous wastes.

    - Procedures for decontamination of the designated area and equipment.

- Select agents and toxins may require additional SOPs and security for storage and handling. Research laboratory staff should refer to VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories.

The SRS is tasked with evaluating the effectiveness of the Research CHP annually and indicating any necessary revisions as identified in VHA Handbook 1200.08. A sample Research CHP is provided in Enclosure 4-1. *Note: This is a sample VHA Research CHP that can be used as a guide to creating a facility Research CHP. Not all components of this sample will be needed at every site, and not all hazards are covered in this sample. Each facility should evaluate the hazards and procedures performed in their particular research program before creating their CHP. The Research CHP should be reviewed (and revised as needed) at least annually.*

VHA Handbook 1200.08 requires that a current inventory of all hazardous research chemicals is maintained and that all research laboratory staff is aware of the location of such inventory.

VHA Handbook 1200.06 requires a semi-annual review of a comprehensive inventory of hazardous chemicals in accordance with Department of Veterans Affairs (VA) Union contracts.

4.3. Chemical Storage

The risk of injuries associated with chemical exposure, unintended reactions, fire, and explosions is minimized when safety procedures and guidelines are followed for chemical storage. Proper storage of research laboratory chemicals comprises five independent factors:

1. Proper identification and containers.
2. Location.
3. Storage devices.
4. Segregation according to chemical compatibility.
5. Shelf life.

Making each of these steps a priority will assist in providing a safe and effective method of chemical storage.

4.3.1. Identification and Containers

All containers must be properly labeled with accurate identification and basic hazard information of the chemical. Research laboratory chemicals should be kept in their original containers, and working quantities transferred to appropriate secondary containers for use in the research laboratory. For secondary containers, transfer chemicals to a smaller container of similar design and composition. All containers must be appropriate for storage of the corresponding

chemical. The manufacturer label on incoming containers must not be removed or defaced. If labels are damaged or missing, they must be replaced by a functional label as described in the Research CHP.

If the integrity of the container is compromised, the chemical or contents must be transferred to another appropriately-labeled, compatible container, and the damaged container disposed of properly. Caps, lids, and other closures must be functional and properly secured to prevent spills or exposure to incompatible conditions or chemicals. The implementation of adequate secondary containment and appropriate chemical segregation is critical to preventing untoward reactions if the container fails. The OSHA Quick Facts Publication, Laboratory Safety Labeling and Transfer of Chemicals, provides further guidance on the requirements for labeling portable secondary containers.

4.3.2. Location

Storage locations should be carefully examined to ensure that the location is adequate for the chemicals being stored. Factors for determining storage location include the frequency of use of the chemical, the amount of materials stored, the individuals accessing the chemicals, fire codes, and all applicable regulations. Locations can be shelves, cabinets, or appliances (such as freezers or refrigerators). Open storage shelves should have a restraint lip to prevent containers from sliding off the shelf. Chemicals should be stored in temperature-controlled storage, away from heat, sunlight, sources of ignition and static electricity, or locations where breakage is likely to occur. Chemicals should not be stored under the sink, on bench tops, above eye level, inside drawers, on the floor, or inside fume hoods.

Limits are provided in National Fire Protection Association (NFPA®) 45, Standard on Fire Protection for Laboratories Using Chemicals, for the total amount of a flammable liquid that can be kept outside of a flammable storage cabinet or flammable liquid storage room as shown in NFPA® 45, Table 10.1.1.(b), which can be viewed through the HEFP Website. Local authorities having jurisdiction may establish more stringent standards.

4.3.3. Storage Devices

Proper implementation and usage of adequate storage devices, such as cabinets, lockers, etc., will help maintain a safer working environment in the research laboratory. A chemical's properties and health hazards will determine the storage device and location necessary to contain and isolate the chemical in the event of a release. Chemicals with significant health hazards should be stored in an appropriate chemical storage cabinet. Non-reactive, non-flammable, and non-corrosive chemicals can be stored in closed containers outside of storage cabinets on secure shelving.

A fundamental means of fire protection is the use of flammable storage cabinets. NFPA®, OSHA, and Uniform Fire Code (UFC) require flammable cabinets to be

designed and constructed to specific requirements. 29 CFR 1910.106, Flammable Liquids, states that metal cabinets are to be constructed as follows:

- Bottom, top, and sides must be at least number 18 gauge sheet steel.
- Cabinet must be double-walled with 1.5 inches of airspace.
- Joints must be riveted, welded, or made tight by equally effective means.
- Door must have a 3-point latch.
- Door sill must be raised at least 2 inches above the cabinet bottom to retain spilled liquid in the cabinet.
- Cabinet must have a “Flammable-Keep Fire Away” legend.

In addition to these requirements, the UFC also requires self-closing doors. Most local authorities use one or more of these standards as a foundation for establishing local codes.

All flammable storage cabinet openings must be properly closed in accordance with requirements of NFPA® 30, Flammable and Combustible Liquids Code. Ventilation, bung removal, and other actions that allow cabinets to be unsealed or exposed will jeopardize the cabinet’s ability to contain materials in the event of a fire. Ventilation kits from the manufacturer are an acceptable option when needed.

Chemical storage cabinets have a defined volume for storage. All containers must be stored upright on the shelves, without stacking. Do not overload the storage cabinets. Do not store chemicals in the spill-containment bottom of the cabinet.

The most common refrigeration used for storing chemicals is explosion-proof and laboratory-safe refrigerators designed to protect against ignition of flammable vapors both inside and outside of the refrigerator. Explosion-proof refrigerators are used in research laboratory spaces designed to meet electrical requirements in NFPA® 70, National Electrical Code. Examples of labels for use on research laboratory refrigerators can be found in NFPA® 45, Section 12.2.1, accessible through the HEFP website. Laboratory-safe refrigerators are designed for a typical research laboratory environment. These refrigerators are designed to eliminate the ignition of flammable vapors from inside the storage compartment of the refrigerator.

Design features of explosion-proof and laboratory-safe refrigerators include:

- Self-closing doors.
- Friction latches or magnetic door gaskets.
- Non-reactive and non-sparking materials for the inner shell.
- Compressor, circuits, and controls located at the top of the refrigerator.

4.3.4. Chemical Compatibility

Chemicals are considered compatible if they do not react with each other. Many chemicals react violently, creating hazardous by-product(s), such as toxic and/or explosive vapors, when mixed together. Materials that are not chemically

compatible (acids/bases; organic/non-organic acids, etc.) should be stored in separate locations to minimize the risk of dangerous reactions.

Major chemical vendors have their own proprietary color-coded system for determining segregation of many common research laboratory chemicals. It is very important to understand that there are a number of limitations of each of these systems. For example, the order of precedence of hazard classes used by chemical manufacturers in their algorithms to assign color codes may differ.

There are many sources for chemical compatibility and storage recommendations, including, but not limited to:

- The CHRIS Manual published by the United States Coast Guard.
- Cole Palmer Chemical Compatibility Database.
- National Oceanic and Atmospheric Administration CAMEO Chemical Database.
- Vanderbilt University Chemical Compatibility Chart.
- Mallinckrodt Specialty Chemicals Co. – Chemical Compatibility List.

Other supplier sites and universal chemical compatibility information can serve as a recommended guideline for chemical storage and be used in combination with container labels, SDSs, manufacturer instructions, and user knowledge for storing and segregating chemicals.

4.3.5. Shelf Life

Some chemicals have expiration dates on their labels, while others have a non-specific shelf life. The Research CHP should develop a protocol for evaluating chemical integrity and shelf life requirements for research laboratory chemicals. Unfortunately, many research laboratories have unused or outdated chemicals that may pose a significant risk. Keeping a current inventory and using a tracking system will identify outdated chemicals for replacement, reassignment, and/or proper disposal.

4.3.6. Minimization of Chemical Inventories

Chemical inventories should be kept as small as possible to minimize storage requirements and risks while being consistent with what is needed for current research protocols. To maintain and more easily monitor the chemical inventory within the research laboratories, only amounts that will be used in a short time frame should be procured.

4.4. Chemical Spill Response

Chemical spill response is governed by 29 CFR 1910.120, Hazardous Waste Management and Emergency Response, 29 CFR 1910.1200, Hazard Communication, and 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories. An effective spill protocol must be developed at each VHA location as part of the Research CHP. This protocol has to take into account the research laboratory facilities, personnel, chemicals and their properties, spill-

control equipment, and availability of internal and external response services. Various spill kits (for example, kits specifically for corrosives, organics, mercury, and/or formaldehyde) may be available in the research laboratory, and personnel should be trained on how to use them. The Chemical Hygiene Officer (CHO)/RCHO and/or Safety Officer will determine if a spill can be cleaned up without risking the safety and health of research laboratory personnel.

Factors to consider for chemical spill response include:

- Dilution or direct local exhaust ventilation available in the spill area.
- Ability to lower the temperature in the spill area to decrease volatility and evaporation, if needed.
- Level of fire protection available (if a flammable or combustible substance is involved).
- Types and quality of PPE present for use by spill responders.
- Availability of direct-reading monitoring equipment to provide responders with real-time airborne concentrations of the substance present.
- Type, quality, and quantity of spill response equipment available at the facility.
- Training and experience of research laboratory personnel or internal emergency response team who might clean up the spill.
- Capabilities and response time of external emergency responders who might clean up the spill.
- Specific layout, employee loading, spill kit accessibility, and other unique conditions of the location of the spill and the immediately surrounding areas.
- Availability of a current and effective facility-specific spill response plan.

A best practice is to periodically inspect (including documentation) for the presence, condition, and shelf life of PPE and other spill response kit items. Any condition affecting the form, fit, or function of the PPE, such as deformity, degradation, or wear and tear, should be grounds for replacement of the equipment.

The SOPs for all spills should include adequate precautions for clean-up because even a minute quantity of some chemicals can pose significant risks, especially in the confined areas found in the research laboratory environment.

Under 29 CFR 1910.1200, employees are trained to clean up small spills of chemicals they normally use. Spill-response personnel from outside the research laboratory must be trained in and follow all provisions of 29 CFR 1910.1200.

4.5. Chemical Transportation and Shipping

Research laboratory staff must often oversee the transfer of chemicals off site. Under 29 CFR 1910.1200, laboratories that ship hazardous chemicals are required to ensure that any container of hazardous chemicals leaving the research laboratory is labeled with the following information:

- Product identification.
- Signal word.
- Hazard statement.
- Pictogram.
- Precautionary statement.

An SDS must be provided with each shipment of chemicals produced at a VHA research laboratory. Under 29 CFR 1910.1450, researchers need to make an effort to provide known hazard classification, signal words, and pictograms to the best of their abilities based on either the chemical product or the chemical substrates. Biological materials shipped with any chemical agents used as preservative (such as formalin or dry ice) should be properly labeled with the agent used, but are not required to have an SDS included with each shipment.

The U.S. Department of Transportation (DOT) regulates the transportation of all hazardous substances including radiological, chemical, and biological materials (including research specimens). DOT provides guidance and training materials to assist in in classifying and describing the hazards, as well as choosing the correct packaging, markings, and labels. The regulations can be found in 49 CFR 171-180, Hazardous Materials Regulations (HMR). DOT authority is limited to the transportation of hazardous materials in commerce; however, DOT regulations must be followed for transporting in private vehicles or between institutions. There is a narrow exemption that allows VHA employees to transport hazardous materials in government vehicles *between VHA facilities.* Additional information is available in 49 CFR 171.1, Applicability of Hazardous Materials Regulations (HMR) to Persons and Functions.

Chemical transfers may be accomplished in several ways in accordance with DOT regulations:

- DOT HMR apply to VHA employees who package, transport, and transfer regulated hazardous materials for entry into commerce (for example, transfer to packing and transport agents regulated by DOT HMR) and to non-federal employees, such as volunteers, contractors, shipping and packing agents, and/or research affiliates who are involved in the packing, handling, or transfer of DOT-regulated hazardous materials. In these

regulated cases, HMR requires VHA compliance with training, proper packing, marking, labeling, and medical certifications for drivers.

- Chemical transfers can be conducted by DOT-compliant commercial packers and shipping agents or commercial DOT-compliant transport providers.
- Transportation of hazardous materials in personal vehicles has specific personal liability issues that VHA employees should strongly consider prior to transport. This includes the possibility that the U.S. Government may not fully or partially provide liability coverage in the event of an accident or personal negligence.

Information regarding the DOT Materials of Trade Exception can be accessed online at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title49-vol2/pdf/CFR-2010-title49-vol2-sec173-6.pdf.

Federal requirements for commercial shipping recommend re-training of personnel every 3 years. The International Air Transport Association (IATA) requires training every 2 years. An overview of the requirements can be found online at: http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm. Current information can be found on the IATA Infectious Substances Website. If any transportation will be by air, IATA requirements should be followed.

4.6. Medical Monitoring

VHA Occupational Health manages medical services and monitoring. Most medical monitoring practices are defined in the VHA Employee Occupational Health Guidebook,as well as in specific local policies and procedures.

A medical monitoring program must include provisions for monitoring of employees exhibiting signs of exposure to a hazardous chemical or if exposure has exceeded the action level (in the absence of an action level, permissible exposure level or other recognized exposure level). Medical monitoring is required for personnel who are required to wear respiratory protection.

An employee believed to have a chemical exposure should follow local protocol, which could include reporting to Occupational Health or the Emergency Department. The treating clinician will request information about the chemical, exposure time and presumed dose, and signs and symptoms experienced. An SDS should be provided by the exposed individual or their supervisor to the treating clinician. The Research Safety Officer or CHO (or designee) should regularly discuss chemical hazards present in the research laboratory with Occupational Health personnel to ensure adequate emergency planning. An exposure risk assessment should be completed by the Research Safety Officer, CHO, or the facility Safety Officer, and reviewed with both research laboratory personnel and Occupational Health staff.

4.7. References and Resources

1. 29 CFR 1910.106, Flammable Liquids.

2. 29 CFR 1910.1200, Hazard Communication.

3. 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories.

4. 49 CFR 171.1, Applicability of Hazardous Materials Regulations (HMR) to Persons and Functions.

5. Centers for Disease Control and Prevention (CDC), Agency for Toxic Substances & Disease Registry (ATSDR), Division of Toxicology and Environmental Medicine.

6. Klaassen, C.D, (2001). *Casarett and Doull's toxicology: The basic science of poisons*, 6th ed.

7. Lawrence Berkeley National Laboratory, Safety Division, Chemical Hygiene Plan.

8. NFPA® 45, Standard on Fire Protection for Laboratories Using Chemicals.

9. NFPA® 30, Flammable and Combustible Liquids Code.

10. NFPA® 704, Standard System for the Identification of the Hazards of Materials for Emergency Response.

11. National Library of Medicine, http://www.nlm.nih.gov/pubs/factsheets/toxnetfs.html.

12. Olishifski, J.B. (1991). *Fundamentals of industrial hygiene*, 3rd ed. National Safety Council.

13. OSHA Standard Interpretation, Laboratory Standard (#20048).

14. VHA Directive 1200, Veterans Health Administration Research and Development Program.

15. VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories.

16. VHA Handbook 1200.08, Safety of Personnel Engaged in Research.

4.8. Enclosure

Enclosure 4-1 Sample Research Chemical Hygiene Plan

Chemical Safety in Research Laboratories

5.1. Introduction

The research laboratory maintains significant quantities of a wide variety of chemicals, some of which are not only highly toxic (acute or chronic), but may also be flammable, combustible, reactive, corrosive, peroxidizable, or explosive. The safe and effective use of chemicals requires a thorough understanding of associated health hazards and dangerous physical properties, as well as knowledge of appropriate means to effectively mitigate hazards. It is the responsibility of the individual using the chemicals to understand the potential hazards of the chemicals in use as well as potential reactions when chemicals are mixed.

5.2. Chemical Hazards

All chemicals have the potential to be hazardous due to toxicity and/or dangerous physical properties, including incompatibilities. Inhalation and skin absorption are the primary routes of exposure in the research laboratory. Health and physical hazards are generally controlled through the use of engineering controls, such as chemical fume hoods (CFHs), bench-top fume hoods, or specialized enclosures (glove boxes) to minimize inhalation exposure. Skin absorption is primarily reduced through the use of laboratory coats and chemical resistant gloves. A glove manufacturer's chemical resistance chart should be consulted prior to chemical use to ensure material compatibility and protection. Chemical splash goggles, face shields, and other protective eyewear should be worn in the research laboratory when there is the potential for eye/face exposure, such as during chemical mixing, vortexing, sonification, centrifuging, etc. Choice of appropriate protection is essential, and a knowledgeable individual should be consulted in selection of protective eyewear.

Incompatible chemicals and materials may be defined as chemicals/materials, which, when mixed, stored, or handled together, can react violently or release toxic substances or toxic gases. It is important for researchers to understand and avoid chemical incompatibilities when using or manipulating chemicals. The ability of researchers to anticipate incompatibility hazards can be complemented by the utilization of an incompatibility tool, such as the National Oceanic and Atmospheric Administration's (NOAA's) CAMEO Chemicals Database, Chemical Incompatibility Tables and Storage Recommendations, incompatibility charts, or by the Safety Data Sheets (SDSs) for the chemicals in question. Incompatibility can also be anticipated by predicting the potential for chemical reaction by assessing the active sites in a chemical formula and what types of products those sites would result in through displacement reactions, acid base reaction, combination reactions, etc.

5.3. Veterans Health Administration (VHA)-Specific Hazardous Chemical Review Requirements

VHA Office of Research and Development (ORD) requires the Principal Investigator to submit a list of hazardous chemicals, as identified or designated by the Occupational Safety and Health Administration (OSHA) and/or the Environmental Protection Agency (EPA), to the Safety Officer for review and approval before a protocol will be reviewed by the Subcommittee on Research Safety (SRS). Detailed information regarding this requirement can be found in VHA Handbook 1200.08, Safety of Personnel Engaged in Research, Section 7.d., and related VHA documents, as well as local policies. *Note: VHA Handbook 1200.08 is currently being reviewed; this guidebook will be updated to reflect handbook changes upon completion.*

Hazardous chemicals are highly regulated and have specific air sampling, engineering controls, administrative controls, personal protective equipment (PPE), training, and medical surveillance requirements. External inspectors may review the research laboratory chemical inventory for these substances as part of regulatory inspections.

5.4. Physical States of Hazardous Airborne Contaminants (HACs)

Because inhalation is a common route of exposure in research laboratories, knowing the different physical states of HACs is useful in understanding how to measure and control them. Particulate HACs include solid and liquid aerosols, dusts, mists, fumes, and fibers. HACs may also exist as gases or vapors. Basic physical properties of airborne contaminants determine how we measure and control them, including the use of engineering and administrative controls and PPE, such as respiratory protection.

5.4.1. Particulates

5.4.1.a. Aerosols

An aerosol is defined as liquid droplets or solid particles of fine-enough particle size to remain suspended in air for a prolonged period of time and includes dusts, mists, fumes, and fibers. Aerosols can become health hazards by inhalation depending on particle size, concentration, and water solubility. Some substances can cause adverse health effects simply upon mucous membrane contact (eye, mouth, or nasal); others require transport to target organs to exert their toxic effect.

5.4.1.b. Dust

Dust is generated by handling, crushing, grinding, rapidly colliding, detonating, and decrepitating (breaking apart by heating) organic or inorganic materials. The term dust is used to describe solid airborne particles that range in size from 0.1 to 25 micrometers (µm).

The greatest risk of exposure to dusts in research laboratories occurs when fine powders of highly toxic materials, such as acrylamide (used to make gels for

electrophoresis) or sodium azide (used as a tissue culture preservative), are manipulated on an open bench. The safest way to minimize exposure to fine toxic powders is to order them pre-mixed or in a single-use container that can be brought to a known volume in a CFH to make up a stock solution. If this is not feasible, the toxic powder should be manipulated in a CFH or high-efficiency particulate air (HEPA)-filtered containment device, such as a bench-top fume hood.

5.4.1.c. Mists

Mists are suspended liquid droplets generated by vapors condensing back into a liquid state, or by liquids breaking up into a dispersed state, such as splashing or atomizing with a compressed gas source. Mists can also be generated by activities, such as centrifuging and vortexing. Examples of mists include sprayed liquids and fog or steam. Mists have multiple routes of entry, including the respiratory system, skin, or eyes.

5.4.1.d. Fumes

Fumes are formed when the material from a vaporized solid (typically a metal) condenses in air that is cooler than the source. The solid particles that make up a fume are extremely fine, usually less than 1.0 µm in diameter. Instances when metal fumes are formed include high-power electrical arcing where the wire and other conductors are atomized, during welding, and when a high-energy laser is used to cut metal. Fumes are especially hazardous because they consist of a very fine particulate and gas phase, each capable of deep lung penetration. In addition, fumes can be generated from metals that are highly toxic, such as hexavalent chromium used in stainless steel.

Historically, the term *fume* was misapplied to describe the mist in the headspace above a concentrated mineral acid (as in “fuming” nitric acid or “fuming” sulfuric acid) and was related to the term *chemical fume hood*. Members of the general public often misuse *fume* when they really mean *vapor*. This is an important distinction to make when selecting engineering controls and respiratory protection because vapors will penetrate particulate filters, and fumes will penetrate gas/vapor sorbents (typically activated charcoal).

5.4.1.e. Fibers

Fibers can include asbestos and synthetic vitreous fibers, such as refractory ceramic fibers (RCFs) used as asbestos substitutes. Fibrous glass and mineral wool are also examples of less durable synthetic vitreous fibers.

Asbestos-containing materials (ACMs) may be found in research laboratories and must be properly identified, maintained, and/or appropriately discarded. Therefore, it is very important to know the location(s) of any ACM(s) identified in the facility baseline asbestos survey. These records are maintained by the facility Asbestos Program Coordinator (APC) and/or Engineering staff. Contact the facility APC with any question regarding ACM in the research laboratory.

Disturbing friable ACM (material that can be crushed or pulverized with hand pressure) may release asbestos fibers that can be inhaled. In addition, non-friable ACM [Transite® (asbestos cement) board panels in older CFHs, Transite® laboratory countertops, etc.] should not be cut, drilled, sanded, or otherwise damaged in ways that could release fibers. Asbestos fibers may be present in old thermal protection gloves, pipe insulation, autoclaves, boiler liners, and vinyl asbestos tiles.

5.4.2. Gases and Vapors

5.4.2.a. Gases

A gas is a basic state of matter in which molecules are unrestricted by cohesive forces with an undefined shape or volume. Gases enter the research laboratory environment as chemical substrates, reaction products, or by-products of animal or chemical protocols. The behavior of gases has been extensively studied so that potential exposure levels can be calculated or predicted.

Physical Hazards Associated with Gases

Gases exhibit various hazards, such as flammability, toxicity, and corrosiveness. Some gases may also displace breathable oxygen and act as simple asphyxiants. The primary physical hazards associated with flammable gases are fire and explosion. Flammable gases can be ignited by static electricity or by heat from a flame or a hot object. Oxygen and other oxidizing gases support combustion of organic materials and, in an oxygen-enriched atmosphere, initiate combustion of materials that are non-flammable under normal conditions. Corrosive gases can cause rapid destruction of skin, eye tissue, and mucous membranes, and degrade various materials used for protection, including fire-resistant clothing. Some gases are not innately corrosive but can become extremely destructive if a small amount of moisture is added. The hazard risks of gases may also be affected by their specific gravity. The relative density of gases, in relation to air (i.e., heavier, lighter, and similar in weight to air), is associated with the risk of accumulating on the floor or towards the ceiling. Knowing where gasses would tend to accumulate if released is important for the placement of ventilation to reduce the hazard.

Compressed gases are potentially hazardous because of the high pressure within the cylinder. A rapid pressure release may propel a cylinder through a wall or whip a tubing line, resulting in injuries or property damage. Most leaks occur at the valve in the top of the cylinder and may involve the valve threads, stem, and outlet; regulator; or pressure-relief devices. Research laboratory staff should not attempt to repair leaking cylinders.

Safe practices for storage, transportation, and use of compressed gas cylinders include:

- Store cylinders in an upright position.
- Keep valve-protection caps on unused cylinders without a regulator.

- Keep cylinders secured to a wall or bench top at all times to prevent sliding or tipping over. It is recommended that, at minimum, one strap located between one half to top third of the cylinder be used. In seismically active areas, two or more straps would be appropriate.
- Group cylinders according to chemical contents.
- Adequately separate cylinders containing oxidizers from cylinders containing flammables in storage with a fire wall or distance of 20 feet, for example.
- Segregate empty cylinders from full cylinders.
- Use an appropriate cylinder dolly for transport.
- Do not use transport dolly for cylinder storage or for securing cylinders connected to any apparatus.
- Do not use grease on tanks containing oxidizing gases.
- Use appropriate regulator based on cylinder contents and pressure.
- The label, not the tank color, identifies the contents.

Additional information about compressed gas cylinders can be found in the VHA General Safety Guidebook.

Health Hazards Associated with Gases

Chemical poisoning by inhalation is the primary health hazard associated with toxic gases. Poisoning may result from even brief exposure to small concentrations of these gases. Systemic effects result when one or more target organs are affected. The symptoms of exposure may be immediate or delayed.

Simple asphyxiation is the primary hazard associated with inert gases or other gases that reduce the concentration of oxygen in the air. These gases are generally colorless and odorless, and increases in gas levels may go undetected and quickly reduce the oxygen concentration to lower than the level necessary to support life. For example, dry ice and liquid nitrogen can act as asphyxiants in low-ventilated areas by reducing the concentration of oxygen. The use of oxygen-monitoring equipment is strongly recommended for enclosed areas where these products are in use.

Dry ice should never be stored in a walk-in cold room because it sublimates at these temperatures, resulting in dangerous levels of carbon dioxide gas that can potentially create an asphyxiant atmosphere that is immediately dangerous to life or health (IDLH).

Escaping liquid nitrogen can form a vapor cloud at very low temperatures and produce an oxygen-deficient atmosphere in confined areas, potentially causing rapid suffocation when sufficient concentrations are released. Confined areas can be non-ventilated rooms, dead-end corridors, and storage rooms. An assessment of the risk associated with the storage of liquid nitrogen in confined areas should take into account the ventilation and the ability for the ventilation to control a nitrogen release caused by normal off-gassing or a breach in the dewar container.

5.4.2.b. Vapors

Vapors are generated when a solid sublimates or a volatile liquid boils or evaporates. Vapors generated from hazardous compounds or chemicals can pose both health and physical hazards. A research laboratory worker who is exposed to toxic vapors may experience local or systemic toxic effects. If the vapors are corrosive, they may cause destruction of the mucosal membranes of the upper and/or lower respiratory tract.

The physical properties of flammable vapors are important in understanding the causes of research laboratory fires involving these substances. If the vapor-air interface above the liquid surface is within the flammable range, and the temperature is above the flash point for that substance, an ignition source can start a fire. Moreover, because the vapor densities of many flammable vapors are heavier than air, they can travel along the floor to distant sources of ignition and flash back along the vapor trail to the source container.

5.5. Characteristics of Chemicals

5.5.1. Corrosives

Corrosive compounds include both acids and bases that cause tissue damage and must be washed off immediately with water if contact is made with skin, eyes, or any sensitive tissues. Acids cause an immediate burning sensation upon exposure. Contact with a base does not usually result in immediate heat or pain but may leave the skin feeling slick or soapy and may result in significant tissue damage, which becomes apparent later. Common corrosives used in laboratories can be found in Table 5-1, Inorganic and Organic Acids, and Table 5-2, Inorganic and Organic Bases.

Some best practices for handling and storing corrosive substances include:

- Procure, store, and use the minimum quantities necessary.
- Purchase shatter-resistant, plastic-coated glass bottles whenever available for strong corrosives. Some manufacturers offer some reagent-grade solvents in high-density polyethylene (HDPE) bottles.
- Determine chemical incompatibilities and ensure appropriate separation for storage.

- Transport all corrosives in a bottle carrier with built-in secondary containment that will contain the entire volume of liquid if a bottle is damaged.
- Use PPE appropriate for the corrosive(s) in use.
- Store acids and bases separately (acids should be in a dedicated acid cabinet).
- Emergency eyewash and safety showers must be accessible and properly maintained in accordance with VHA Directive 7704, Location, Selection, Installation, Maintenance, and Testing of Emergency Eyewash and Shower Equipment.
- The integrity of PPE, storage cabinets, and all other safety equipment must be assessed regularly.

5.5.1.a. Acids

Table 5-1 provides examples and storage guidelines for inorganic and organic acids.

Table 5-1: Inorganic and Organic Acids

Inorganic Acids	Chemical Examples	Storage Guidelines
Non-Oxidizing Inorganic Acids	Boric acid, fluoroboric acid (48-50%), hydrobromic acid, hydrobromous acid, hydriodic acid, hydrochloric acid, hydrochlorous acid, hydrofluoric acid, hydrofluosilicic acid, Iodic acid, nitrous acid, o-Phosphoric acid, phosphorous acid, sulfamic acid (solid).	Segregate from oxidizing acids and bases. Store hydrofluoric acid in original container.

Inorganic Acids	Chemical Examples	Storage Guidelines
Oxidizing Inorganic Acids	Concentrated acids, including chromic acid, chlorosulfonic acid, nitric acid, perchloric acid, sulfuric acid, sulfurous acid.	Segregate individually from strong inorganic acids and bases and flammable/combustible organics. Strong oxidizing acids are incompatible with each other and other strong non-oxidizing mineral acids. Each must be stored separately in its own secondary containment in a corrosive storage cabinet. Manufactured from compatible materials. Store away from organic acids.
Organic Acids	**Chemical Examples**	**Storage Guidelines**
Flammable Organic Acids	Glacial acetic acid, formic acid, picric acid.	Store in a separate secondary containment within a flammable liquid cabinet.
Non-Flammable Organic Acids	Acetylsalicylic acid, ascorbic acid, butyric acid, caproic acid (hexanoic acid), benzoic acid, chloroacetic acid, citric acid, lactic acid, maleic acid, oxalic acid, salicylic acid, trichloroacetic acid, trifluoroacetic acid, valeric acid (pentanoic acid).	Store in an acid or corrosives cabinet, segregated from strong non-oxidizing inorganic acids. Each must be stored in their own secondary containment.

5.5.1.b. Bases

Table 5-2 provides examples and storage guidelines for inorganic and organic bases.

Table 5-2: Inorganic and Organic Bases

Inorganic Bases	Chemical Examples	Storage Guidelines
Inorganic Bases	Iodine, sodium hypochlorite (5.65-6%), zinc chloride, or zinc dichloride.	Store in a dry environment.
Inorganic, Liquid Strong Bases	Ammonium hydroxide solution, potassium hydroxide solution, sodium hydroxide solution.	Store away from acids.

Inorganic, Solid Strong Bases	Barium hydroxide, calcium hydroxide, lithium hydroxide, potassium hydroxide, sodium hydroxide.	Store in a dry environment.
Organic Bases	**Chemical Examples**	**Storage Guidelines**
Organic, Liquid Bases	Amines (diethanolamine), imidazole.	Store away from acids.

5.5.2. Water Reactives

Some research laboratories use chemicals that are incompatible with water. Reactions include release of oxidizing, toxic, or flammable gases. An example would be sodium metal that burns violently upon contact with water. Safe storage of water reactives usually involves immersion in a water insoluble liquid (oil) that will prevent the intrusion of moisture.

5.5.3. Air Reactives (Pyrophorics, Air Sensitive)

Pyrophorics are defined in 29 Code of Federal Regulations (CFR) 1910.1200, Hazard Communication, as chemicals that ignite within 5 minutes after coming in contact with air. Air-reactive substances are typically reacting with the moisture in the air. These reagents are often found in synthetic organic chemistry laboratories. An example of an air reactive is t-butyllithium.

These substances can be extremely dangerous when mishandled and must only be used by trained, experienced chemists because they require special handling, storage, and use. Air reactives must be handled carefully to prevent uncontrolled ignition because combustion will occur under virtually all circumstances where the material is exposed to air.

5.5.4. Oxidizers

Oxidizers are defined by 20 CFR 1910.1200 as chemicals other than a blasting agent or explosive that cause or contribute to combustion in other materials, thereby causing fire independently or through the release of oxygen or other gases.

Liquid and solid oxidizers are incompatible with many chemicals and must be segregated in storage and use. Solid oxidizers may be stored together subject to chemical compatibility within their class. Moreover, they must be stored away from any incompatible liquid chemical reagents or substances. Liquid oxidizers should be stored away from everything else, each in its own secondary containment. Never store strong liquid oxidizers near fuels (flammable organic compounds, finely divided metals, and alkali and alkaline earth metals) or strong reducing agents. Store strong oxidizers in a cool, dry place. Avoid heat, moisture, sunlight, and contaminating substances.

Strong oxidizers often contain multiple oxygen atoms or halogen atoms (fluorine, chlorine, bromine, and iodine, for example). Table 5-3 lists some examples of strong oxidizers, liquid oxidizers, and solid oxidizers. The lists are not all-inclusive.

Table 5-3: Strong, Liquid and Solid Oxidizers

Strong Oxidizers	
BO_4^{3}: Perborate	IO_3^-: Iodate (Sodium iodate, $NaIO_3$)
BrO_4: Bromate	IO_4^-: Iodic (periodic acid, HIO_4)
ClO_3: Chlorate	MnO_4^-: Permanganate
ClO: Hypochlorite	NF_x: Nitrogen fluorides
ClO_2: Chlorite	NO_2^-: Nitrite
ClO_4: Perchlorate	NO_3^-: Nitrate
CrO_3: Chromium trioxide	N_2O_x: Nitrogen oxides
$Cr_2O_7^{2-}$: Dichromate (Potassium dichromate, $K_2Cr_2O_7$)	O_2: Oxygen (g)
CrO_4^{2-}: Chromate	SO_5: Peroxymonosulfate
F_2: Fluorine (g)	$S_2O_8^{2-}$: Persulfate
H_2O_2: Hydrogen peroxide	
Liquid Oxidizers	
Br_2: Bromine	$HClO_4$: Perchloric acid
H_2CrO_4: Chromic acid	NaClO: Sodium hypochlorite solution
H_2O_2: Hydrogen peroxide (>8%)	H_2SO_4: Sulfuric Acid
HNO_3: Nitric acid	
Solid Oxidizers	
$(NH_4)_2Cr_2O_7$: Ammonium dichromate	KNO_3: Potassium nitrate
NH_4NO_3: Ammonium nitrate	$KMnO_4$: Potassium permanganate
$(NH_4)_2S_2O_8$: Ammonium persulfate	$K_2S_2O_8$: Potassium persulfate
$Ba(ClO_2)_2$: Barium chlorite	$Na_2Cr_2O_7$: Sodium dichromate
$Ba(NO_3)_2$: Barium nitrate	$AgNO_3$: Silver nitrate
$Ba(ClO_4)_2$: Barium perchlorate	Ag_2O: Silver oxide
CrO_3: Chromium trioxide	$NaIO_3$: Sodium iodate
$FeCl_3$: Ferric chloride	$NaNO_2$: Sodium nitrite
Fe_2O_3: Ferric trioxide	$NaNO_3$: Sodium nitrate
HIO_4 or H_5IO_6: Periodic acid	$NaIO_4$: Sodium periodate
K_2CrO_4: Potassium chromate	$NaMnO_4$: Sodium permanganate
Solid Oxidizers (cont)	
K_2CrO_7: Potassium dichromate	$Na_2S_2O_8$: Sodium persulfate

KIO_3: Potassium iodate	

Some best practices for handling and storing oxidizers include:

- Do not use a dry chemical extinguishing agent on oxidizer fires.
- Special training and equipment is recommended for cleaning an oxidizer spill.
- Monitor the shelf life of the oxidizer after opening the container. Changes in the physical characteristics of the oxidizer (color change, crystallization, etc.) may suggest degradation, decomposition, or instability.
- These compounds should be labeled with “Date Opened” as outlined in the Research Chemical Hygiene Plan (CHP).
- Monitor oxidizers for contamination with trace amounts of incompatible materials (metals) that can cause oxidizers to become unstable and reactive.
- Use a designated wash-down fume hood when heating perchloric acid. The fume hood should be labeled “Perchloric Acid Hood Only: Not for use with Organic Chemicals.”

5.5.5. Explosives

Use of any hazardous chemical that is a Department of Transportation (DOT) explosive should be strictly prohibited in VHA research facilities. However, certain research laboratory reagents can fall into the DOT explosives category when they degrade over time and become shock-sensitive. These reagents are then classified as a reactive hazardous waste. Certain dehydrated reagents or research laboratory chemicals that can become shock-sensitive include dinitro- and trinitro-phenol compounds, such as 2,4-Dinitrophenol; 2,4,6-Trinitrophenol (picric acid), and diethyl ether. Other reagents can react with metals to form explosive azides, picrates, fulminates, and styphnates. Under the right conditions, peroxidizable reagents can form organic peroxides over time.

The facility Safety Officer and Research Chemical Hygiene Officer (RCHO) should be contacted immediately if a bottle is suspected to contain a dry dinitro-compound or trinitro-compound, such as picric acid. These compounds should only be handled by trained, experienced reactive chemical contractors.

Sodium azide can form shock-sensitive azide compounds with metal plumbing components (such as sink traps) if poured down the drain. Because there have been reports of fatalities when shock-sensitive azides were detonated by striking a metal sink trap, metal sink traps in old research laboratories should be tested for the presence of explosive compounds prior to disassembly. Testing may require the services of a specialty contractor.

Fume hoods and duct transitions should be tested for the presence of perchlorates before dismantling them whenever the possibility exists that they were used to perform procedures involving perchloric acid in the past. There have been reports of fatalities when shock-sensitive perchlorates were detonated by striking the fume hood or duct transition during demolition. Testing may require the services of a specialty contractor.

5.5.6. Organic Peroxides

Organic peroxides include any organic compound having a double oxygen or peroxy (-O-O-) group in its chemical structure, such as dibenzoyl peroxide, cumene hydroperoxide, and peroxyacetic (or peracetic) acid.

The procurement, storage, and use of organic peroxides should be strictly controlled in VHA research laboratories and should require prior approval from the SRS.

Certain chemicals, most often organic peroxide formers (peroxidizables), can become unstable if stored beyond their expiration date, exposed to light, or exposed to air. Some of these organic peroxides are shock-sensitive and constitute a serious safety hazard. Peroxidizable chemicals can be tested through a variety of means for peroxide formation. However, because a number of factors can hasten peroxide formation (improper closure, exposure to light, elevated temperatures, and depletion of peroxide inhibitors), there is a potential for peroxide formation prior to expiration dates.

The Lawrence Berkeley National Laboratory Safety Division Chemical Hygiene and Safety Plan includes a table with examples of peroxide-forming materials and their relative safe storage times. This table can be accessed on the Lawrence Berkeley Laboratory Website.

Some best practices for handling and storing peroxide-forming chemicals include:

- Ensure that the container has a peroxide-warning sticker and a label consistent with the requirements of the local Research CHP, including provisions for monitoring the date received and the date opened.
- Track the date(s) when the containers are opened. Discard if last date opened is beyond the discard date.
- Store in a dry area away from heat and light sources.
- Discard the following chemicals *3* months after receipt: butadiene, isopropyl ether, sodium amide, chloroprene, potassium amide, tetrafluoroethylene, divinyl acetylene, potassium metal, and vinylidene chloride.
- Discard other peroxide-forming chemicals 6 months after opening or within 12 months after receipt if unopened.

- Contact the Safety Office and RCHO for immediate support for a container that appears to have exceeded its expiration date or exhibits signs of degradation.

- Do not move any container with visible crystals; they may be unstable organic peroxides! Any such container should be evaluated by a reactive chemical expert.

- Do not evaporate or distill *to dryness* (less than 10% starting volume) any material that is listed as a peroxide hazard on distillation. Evaporating solvent to dryness could leave shock-sensitive peroxide residue in a round-bottom flask.

5.5.7. Flammable Materials

The fire tetrahedron (Figure 5-1) defines the chemical reaction by the components and conditions upon which combustion will occur: fuel, oxidizer, source of ignition, and self-sustaining reaction. While the presence of the first three components makes it possible for a fire to occur, removal of one of the four components extinguishes a fire. Even circumstances in which a chemical reaction plays a significant role, all components of the fire tetrahedron are necessary. For example, when water and sodium metal reacts, the heat of the reaction is the source of ignition, and the hydrogen liberated in the course of the reaction acts as the fuel.

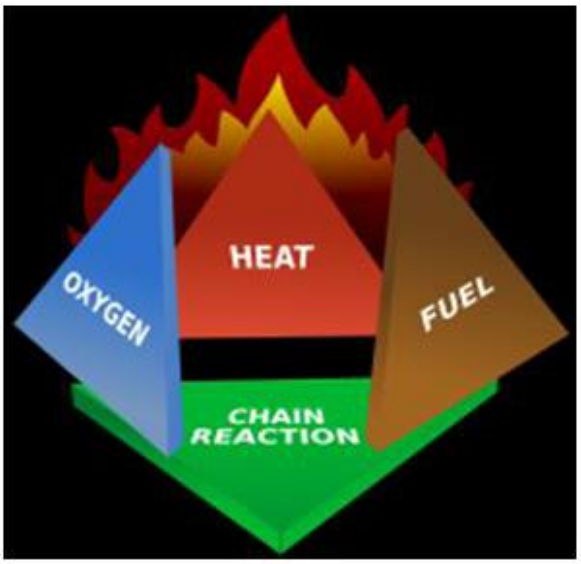

Figure 5-1: Fire Tetrahedron (Source: Gravity and Momentum, 2011)

5.5.7.a. Flammable Solids

Flammable solids are defined as desensitized explosives or, as stated in 49 CFR 173.124, Class 4, Divisions 4.1, 4.2 and 4.3 - Definitions, “self-reactive materials that are thermally unstable and can undergo a strongly exothermic decomposition even without participation of oxygen (air)” and “readily combustible solids.” Under

normal conditions, flammable solids (not explosives or blasting agents) can cause combustion or burn vigorously and persistently if ignited. Many flammable metals burn if divided into shavings, powders, or turnings, and distributed in the air. Flammable solids can be ignited through heat, moisture absorption, or air exposure (pyrophoric), including spontaneously combustible, self-heating, and water reactive compounds. For example, sodium metal, in the presence of water, produces hydrogen gas that is then ignited by the heat of reaction.

Fires involving flammable metals, such as calcium, lithium, magnesium, potassium, and sodium, are difficult to extinguish using a conventional dry chemical-type fire extinguisher. A flammable metal fire requires a special Class D fire extinguisher that utilizes a dry powder agent to smother the fire and absorb heat. A water fire extinguisher should never be used on a flammable metal fire because the water will react with the metal to make the fire much more intense. More information can be found in the VHA Fire Safety Guidebook.

5.5.7.b. Flammable Liquids

Flammable liquid means a liquid with a flash point of 93 degrees Celsius (199.4 degrees Fahrenheit) or less. The Hazard Communication Standard combines flammable and combustible liquids into one hazard class, Flammable Liquids, based on the incorporation of the United Nations Globally Harmonized System (GHS) of Classification and Labeling of Chemicals definitions. See Chapter 4, Management of Hazardous Chemicals in Research Laboratories, for detailed hazard communication and GHS information.

The flash point is the lowest temperature at which a liquid gives off enough vapors to form an ignitable mixture in the air above its surface. The flash point varies with different chemicals and is used along with the boiling point to classify the relative fire hazards of flammable liquids. Flash point applies to *vapor only* (not gas) and designates a temperature at which an ignitable vapor concentration *can be present*, not where ignition will definitively occur.

5.5.7.c. Flammable Range

When the temperature of a liquid is higher than its flash point, enough molecules of vapor escape to create a potentially flammable mixture in the air. Fire can result if the concentrations of vapor and air are within the flammable range.

Flammable range is determined by the concentration between two parameters: the lower explosive limit (LEL) or lower flammable limit (LFL) and the upper explosive limit (UEL) or upper flammable limit (UFL). Below the LEL/LFL, the concentration of flammable vapor in the air is not sufficient to support combustion. Above the UEL/UFL, the concentration of flammable vapor in the air is too high to support combustion. Gases do not have flash points because they do not form vapor above the surface.

Table 5-4 shows a list of common research laboratory solvents and their physical properties related to their fire hazard. The information in Table 5-4 was adapted

from the National Institute of Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards.

Table 5-4: Physical Properties of Common Lab Solvents as They Relate to Exposure Potential and Fire Hazard

Common Name	CAS Number	FP (˚F)	BP (˚F)	VP (mmHg)	LEL (%)	UEL (%)	Flammable Class
Acetone	67-64-1	0	133	180	2.5	12.8	1B
Acetonitrile	75-05-8	42	170	73	3.0	16.0	1B
Benzene	71-43-2	12	176	75	1.2	7.8	1B
Carbon disulfide	75-15-0	22	116	297	1.3	50.0	1B
Diethyl ether, Ethyl ether	60-29-7	49	94	440	1.9	36.0	1A
Ethyl alcohol	64-17-5	55	173	44	3.3	19	1B
N-Hexane	110-54-3	-7	156	124	1.1	7.5	1B
Methyl alcohol	67-56-1	52	147	96	6.0	36	1B
n-Propanol, 1-Propanol	71-23-8	72	207	15	2.2	13.7	1B
Isopropanol, Isopropyl alcohol	67-63-0	53	181	33	2.0	12.7	1B
Toluene	108-88-3	40	232	21	1.1	7.1	1B
m-Xylene	108-38-3	82	282	9	1.1	7.0	1C

CAS: Chemical Abstracts Service
FP: Flash Point
BP: Boiling Point
VP: Vapor Pressure

5.5.7.d. Classification Criteria

A flammable liquid shall be classified in one of four categories as shown in Table 5-5.

Table 5-5: Criteria for Flammable Liquids

Category	Criteria
1	Flash point < 23°C (73.4°F) and initial boiling point ≤ 35°C (95°F)
2	Flash point < 23°C (73.4°F) and initial boiling point > 35°C (95°F)
3	Flash point ≥ 23°C (73.4°F) and ≤ 60°C (140°F)
4	Flash point > 60°C (140°F) and ≤ 93°C (199.4°F)

Source: 29 CFR 1910.1200, Appendix B

Some best practices for handling and storing flammable liquids are as follows:

- Flammable liquids should be segregated from oxidizers and certain corrosives, such as concentrated sulfuric acid and nitric acid, to protect research laboratory staff from fire hazards.
- Glacial acetic acid and propionic acid should be stored in small quantities in an approved flammable liquid cabinet, each in their own secondary containment.
- Procure, store, and use the minimum quantities of chemicals.
- Keep in-use quantities on an open bench to the minimum needed for the tasks being performed that day.
- Store quantities of flammable liquids greater than 10 gallons in one sprinklered research laboratory room in a compliant flammable liquid storage cabinet or inside a dedicated flammable liquid storage room.
- If flammable liquids need to be refrigerated, store in a special explosion-proof refrigerator, designed and manufactured for storing flammable liquids. This type of refrigerator has intrinsically safe electrical components on the motor and wiring located outside of the refrigerator, as well as blowout panels.
- Purchase polymer-coated glass bottles whenever a glass container is required. This will contain liquid if the bottle is damaged. Bottles should be transported in a bottle carrier with built-in secondary containment.
- Prior to use, inspect electrical equipment for defects and other potential ignition sources in areas where flammable vapors may accumulate.
- Keep flammable solvent wipes away from ignition sources.
- Do not pour flammable liquids into drains.

- Electrically bond and ground metal safety cans or containers prior to dispensing or receiving flammable liquids at temperatures above their flash points.

5.5.7.e. Auto-Ignition Temperature

The auto-ignition temperature is the temperature at which a product can undergo spontaneous ignition. These temperatures are very high, commonly in the hundreds of degrees Fahrenheit. The auto-ignition temperature is important in evaluating research laboratory procedures that involve heating hazardous chemicals, evaluating storage conditions that are not climate-controlled, and assessing potential risk(s) in fire situations.

5.6. Toxicology

Toxicology is the study of the adverse effects of toxins on living organisms. Factors influencing toxic effect include dose, frequency, duration, and route(s) of exposure. Typically, toxic effects are classified as acute or chronic.

5.6.1. Dose

Dose refers to the amount of a substance administered or absorbed over a specified time interval. Oral dosing is expressed in milligrams of substance per kilogram (mg/kg) of the exposed subject over time. Inhalation dose is the product of particulate, gas, or vapor concentration [milligrams per cubic meters (mg/m^3) and/or parts per million (ppm)] multiplied by the time of exposure.

Acute adverse health effects, often expressed as lethalities, are used to characterize dose. Lethality is often expressed as lethal dose 50 (LD_{50}). The term LD_{50} refers to the dose of a toxic substance that kills 50% of a test animal population. For airborne exposures, lethality is expressed as a lethal concentration 50% (LC_{50}).

5.6.2. Acute vs. Chronic Exposure

Acute exposures typically refer to a one-time high-level exposure that occurs over a short period of time. This type of exposure is usually associated with hazards from inhalation of high concentrations of hazards, or from direct skin contact by splash or immersion. The symptoms and effects are usually immediately apparent, but onset may be delayed. Acute exposure can cause reversible or irreversible damage. For example, a splash of sulfuric acid will cause an immediate burn to the skin.

Chronic exposures are repetitive or continuous low-level exposures that occur over long periods of time. The symptoms and effects are usually cumulative and/or delayed, and the effects can be reversible or irreversible. For example, prolonged exposure to many organic solvents, even at low doses, may lead to liver damage.

5.6.3. Local vs. Systemic Exposure

Local effects refer to the action site of an agent or the point of contact. The site may include skin, mucous membranes (mouth, nose, eyes), respiratory tract, or gastrointestinal tract.

Systemic effects occur when the agent travels from the site of entry to a target organ or organ system where the damage is inflicted. Transport primarily occurs through the circulatory system.

5.6.4. Routes of Entry

Hazardous chemicals may enter the body through four principal routes: inhalation, skin absorption, ingestion, and injection. Each route of entry is unique in terms of potential for exposure because it influences the ability for chemicals to be transported to other sites and/or metabolized. Hazardous chemicals can produce local (site of entry) effects or exert their effects on a target organ or organ system. Some chemicals can cause both local and systemic effects. For example, phenol is a chemical that produces burns (local) and liver and central nervous system (systemic) effects.

Inhalation is usually the most rapid and efficient route of entry due to the large surface area of the lungs and the very thin layer of cells that act as a protective barrier to the bloodstream.

The skin is the largest organ of the body and is an effective barrier against a wide variety of chemicals. Skin absorption can occur through broken or unbroken skin and can result in local or systemic damage. Wet skin and mucous membranes may support local chemical reactions or aid in transport through the dermal barrier. Commonly used chemicals that are easily absorbed through intact skin have a “SKIN” designation after the permissible exposure limit (PEL), threshold limit value (TLV®), and recommended exposure limit (REL). Common examples include benzene, carbon disulfide, phenol, and toluene. Special chemical-resistant gloves (above and beyond nitrile exam-style gloves typically worn by researchers) may be required when working with highly toxic substances, strong corrosives, and allergens/dermal sensitizers, depending on potential skin contact.

Ingestion can result from poor personal hygiene, touching your face, poor workplace housekeeping, or improper storage of food or beverages in the research laboratory. The Research CHP should prohibit eating and drinking, mouth pipetting, chewing gum, and applying cosmetics in the research laboratory.

Injection can occur following an accidental puncture or laceration from chemical-contaminated sharps (needles, scalpels, razors, etc.) or broken glass. Injection is a means for contaminants to be placed directly in the bloodstream and to reach a target organ or organ systems. Appropriate precautions, such as using PPE, tongs, and dustpan and brush, need to be taken when dealing with contaminated broken glass. Recapping needles and emptying sharps containers when they are

three fourths full can help prevent accidental injection when handling contaminated sharps.

Detailed information on toxicology, including central nervous system depressants, neurotoxins, bone marrow suppressants, and asphyxiants (among others) can be found in Enclosure 5-1, Additional Toxicology Information.

5.6.5. Exposure Guidelines and Standards

Several exposure guidelines and standards have been developed to quantify exposure levels for various chemicals. These include PEL, TLV®, and REL. Workplace exposures are evaluated using a time-weighted average (TWA), which measures the concentration of a hazardous air contaminant that most workers can be repeatedly exposed to during an 8-hour day, 40-hour week without developing adverse acute or chronic effects.

OSHA has established PELs as legal standards of exposure limits designed to protect employees. PELs for numerous chemicals are published in 29 CFR 1910.1000 through 1910.1052. Some states have OSHA-approved programs that may have established lower PELs than the Federal OSHA standards.

TLV® is defined as "Airborne concentrations of chemical substances under which conditions it is believed nearly all workers can be exposed to repeatedly day after day without adverse health effects" by the American Conference of Governmental Industrial Hygienists (ACGIH®). TLVs® can be purchased directly from ACGIH® online. NIOSH has guidelines referred to as RELs that can be viewed online at: http://www.cdc.gov/niosh/topics/chemical-safety/.

TLVs® and RELs are guidelines that are not legally enforceable. A PEL, TLV®, or REL can be established for an 8-hour TWA, a 15-minute or 30-minute short-term exposure limit (STEL), or as a maximum exposure (ceiling limit). Table 5-6 provides a summary of these values.

Table 5-6: Summary on TWA, STEL, and Ceiling Limit

Exposure Guideline	Standard
TWA	This value is the TWA concentration most workers can be repeatedly exposed to during an 8-hour day, 40-hour week without developing adverse acute or chronic effects. Excursions in worker exposure levels may exceed three times the standard TWA for no more than a total of 30 minutes in a workday. Under no circumstances should they exceed five times the

	standard TWA, provided the TWA is not exceeded. This is called an *implicit ceiling*.
STEL	An STEL is a 15-minute or 30-minute average exposure period, repeated no more than 4 times a day, with at least 1 hour between successive exposures, provided the 8-hour TWA is not exceeded. The STEL supplements the TWA where acute effects from high short-term exposures are recognized.
Ceiling	This value is never to be exceeded during the work period.

Additional information on TWA, STEL, and ceiling limits can be found in the VHA Industrial Hygiene Guidebook.

5.6.6. Action Levels and IDLH

OSHA and NIOSH have established action levels for certain chemicals as guidelines for initiating medical surveillance, increased industrial hygiene and/or biological monitoring, and sometimes other program elements such as respiratory protection and training. Action levels are generally set at one-half of the PEL or REL.

OSHA and NIOSH have also developed IDLH exposure levels. According to 29 CFR 1910.120, Hazardous Waste Operations and Emergency Response (HAZWOPER), IDLH is: “An atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere.” IDLH values are listed in the NIOSH Pocket Guide to Chemical Hazards.

5.7. References and Resources

1. Centers for Disease Control and Prevention (CDC) Agency for Toxic Substances & Disease Registry (ATSDR), Division of Toxicology and Human Health Sciences.

2. Klaassen, C.D. (2001). *Casarett and Doull’s toxicology: The basic science of poisons*, 6th ed.

3. Lawrence Berkeley National Laboratory, Safety Division, Chemical Hygiene and Safety Plan.

4. NFPA® 45, Standard on Fire Protection for Laboratories Using Chemicals.

5. NFPA® 30, Flammable and Combustible Liquids Code.

6. NFPA® 704, Standard System for the Identification of the Hazards of Materials for Emergency Response.

7. National Library of Medicine.

8. Olishifski, J.B. (1991). *Fundamentals of industrial hygiene*. 3rd ed. National Safety Council.

9. OSHA Standard Interpretation, Laboratory Standard (#20048).

5.8. Enclosure and Fact Sheets

Fact Sheets for Research Laboratory Guidebook

The following fact sheets contain quick-reference information relevant to this chapter:

3.2 Health Hazards and Chemical Toxicity
3.3 Benzene
3.4 Ethylene Oxide
3.5 Formaldehyde
3.6 Glutaraldehyde
3.7 Phenol
3.8 Diethyl Ether
3.9 Acrylamide
3.10 Ethidium Bromide
3.11 Mercaptoethanol
3.12 Xylene
3.13 Toluene
3.14 Hydrogen Fluoride/Hydrofluoric Acid
3.15 Mercury
3.16 Organic Mercury Compounds
3.17 Methylene Chloride
3.18 Nanoparticles
10.1 Compatible Chemical Storage
10.2 Flammable Chemical Storage
10.3 Peroxides and Peroxide-Forming Chemical Storage

Enclosure 5-1 Additional Toxicology Information

Research Laboratory Ventilation

6.1. Introduction

Research laboratory ventilation includes general ventilation that ensures a comfortable working environment for employees and creates pressure differentials between laboratory and non-laboratory spaces. Ventilated research laboratory equipment, such as fume hoods and biological safety cabinets (BSCs), remove hazardous chemical vapors, gases, and particulates for employee safety. It is important to maintain a balance between general ventilation and fume hood exhaust to ensure that both systems work effectively. The guidelines and procedures described throughout this chapter are intended to assist Veterans Health Administration (VHA) Research Service, Safety, and Engineering staff with:

- Selecting appropriate ventilation engineering controls.
- Establishing ventilation system design and operating specifications.
- Ensuring proper operation of research laboratory ventilation systems.

The American National Standards Institute/American Industrial Hygiene Association (ANSI/AIHA) Standard Z9.5, Laboratory Ventilation, recommends implementation of a Laboratory Ventilation Management Program to ensure the proper design, operation, maintenance, and use of ventilation systems, as well as the protection of research laboratory staff working with potentially hazardous materials.

Note: This chapter focuses on fume hoods as a major component of a research laboratory ventilation system. Detailed information on BSCs can be found in the Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th edition.

6.1.1. Hazard Assessment

Research laboratory staff is potentially exposed to a wide variety of airborne hazards. These hazards must be identified and evaluated to ensure appropriate exposure-control devices and establish appropriate operating specifications and performance criteria. The assessment of research laboratory hazards includes the evaluation of: potential hazards present and affiliated safety requirements, as well as occupancy levels and comfort requirements.

Principal Investigators, working in conjunction with the Research Service, the Safety Office, and the Facilities Management Service (FMS) staff, can determine proper research laboratory ventilation requirements by evaluating:

- The types of hazards present according to research laboratory procedures conducted.
- Hazard generation characteristics (gases, vapors, mists, dusts, etc.).

- Quantity of materials used or generated during research laboratory procedures.
- Frequency and duration of hazard generation.

6.1.2. Types of Hazardous Procedures

The quantity, toxicity, and physical characteristics of airborne hazardous materials generated during research laboratory procedures will dictate the level of ventilation control required for a safe work environment. Principal Investigators should coordinate with the Research Service and Safety Office to characterize hazardous work procedures in order to estimate the volume and potential generation rates of hazardous materials. The following categories can be helpful for characterizing hazardous procedures:

- Proper storage: Emissions may occur from improperly sealed containers during storage. The rate and quantity of generation may be small, but not negligible. Complaints of odors (for example, in areas where containers of mercaptans or amines are not stored in ventilated enclosures) could indicate escape of small concentrations of hazardous materials from inadequately sealed containers.

- Closed process: A closed process refers to the use of hazardous materials while contained within an experimental apparatus including beakers, flasks, tubing, or research laboratory equipment. The volume of material that could be released in the event of a catastrophic incident such as accidental over-pressurization, damage to the system, or leaks, should be estimated. Closed processes are often used in chemical dispensing, solvent recycling, sterilization, and analytical procedures.

- Normal process: A normal process typically involves procedures that result in low emissions with little energy added to the process. Generation of materials is typically through diffusion or evaporation. Some procedures in a normal process include liquid transfers (pouring) and small-quantity weighing. Pipetting is an example of a normal process.

- Complex process: A complex process generally involves procedures that apply significant energy and that have the potential to produce a larger volume of airborne contaminants. Such processes might include volatile reactions, sonication, homogenization, centrifugation, heating and boiling, and exothermic reactions. The application of energy complicates the determination of contaminant-generation rates.

6.2. Research Laboratory Ventilation Design and Operation

Research laboratory design should maximize the utility of the exhaust and air supply systems to:

- Satisfy the HVAC Design Manual for New, Replacement, Addition, and Renovation of Existing VA Facilities (VA HVAC Design Manual), exhaust

flow requirements of exposure control devices, such as fume hoods, under all modes of operation.

- Provide a healthy environment without compromising the performance of vented equipment.
- Provide a comfortable and productive work environment for research laboratory occupants.
- Ensure energy conservation.

Worker and general public safety requirements are top priority. Primary containment is provided through the use of ventilated research laboratory equipment and is supplemented through secondary measures such as research laboratory design and ventilation. Multiple levels of containment minimize risk to non-laboratory areas such as offices and corridors.

6.2.1. Air Change Rates and Distribution for Research Laboratories

Research laboratory air distribution systems should minimize energy consumption, distribute sufficient quantities of air to meet indoor air quality (IAQ) standards, provide occupants with a comfortable work environment, and most importantly, effectively distribute air that will support the operation of ventilated equipment. Recommended air changes per hour (ACHs) for research laboratories are listed in the VA HVAC Design Manual, Chapter 6, Applications, in the Office of Construction & Facilities Management (CFM) Technical Information Library (TIL). There is also a design guide for specific facility types available in the TIL.

6.2.2. Specification of Air Flow Rates for Research Laboratories

Potential sources of contaminant emissions should be identified, and ventilation controls should be specified to control emissions at the source. The required exhaust flow should be sufficient to satisfy the exhaust demands of all fume hoods and exposure control devices functioning under a wide range of operating conditions. Research laboratory air flow rates should be based on total exhaust flow for a negatively pressurized research laboratory, or on supply air for a positively pressurized research laboratory (for surgical suites). All research laboratory areas that have the potential for releasing hazardous airborne contaminants should operate under negative pressure with respect to adjacent non-laboratory spaces. The required pressure differential between the spaces should be defined by the design specifications.

A simple test to determine if a research laboratory is under positive or negative pressure involves placing a tissue along the bottom edge of a closed doorway into the research laboratory. The tissue will move in the direction of air flow (into the research laboratory indicates negative pressure; outside the research laboratory indicates positive pressure). As an alternative, glycerin and propylene glycol-based smoke generation devices are also available. Problems detected with research laboratory air flow should be reported to FMS.

The volume and quality of air supply to the research laboratory should be sufficient to meet IAQ requirements as specified by VA HVAC Design Manual, which is based on American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and other applicable codes and standards.

The air flow control systems should be sufficient to maintain the required exhaust and supply-air volumes and should be periodically verified by designated staff. General research laboratory ventilation should not interfere with exhaust air flow requirements of externally-ducted ventilated equipment.

Supplemental information on general research laboratory design specifications can be found in Enclosure 6-1. Detailed information on research laboratory exhaust ventilation is provided in Enclosure 6-2.

6.3. Fume Hood Selection

Fume hoods are often the primary means of protecting personnel from airborne hazards and should be considered an integral part of the overall building heating, ventilation, and air conditioning (HVAC) system. Any design process that involves selection and installation of research laboratory fume hoods should consider:

- Any user-specific requirements.
- Results of a hazard assessment.
- Specifications required for type of research.
- Specific containment and fume hood size requirements.
- Satisfactory performance testing of fume hood monitoring and control configurations.

Figure 6-1 shows different containment devices and potential applications.

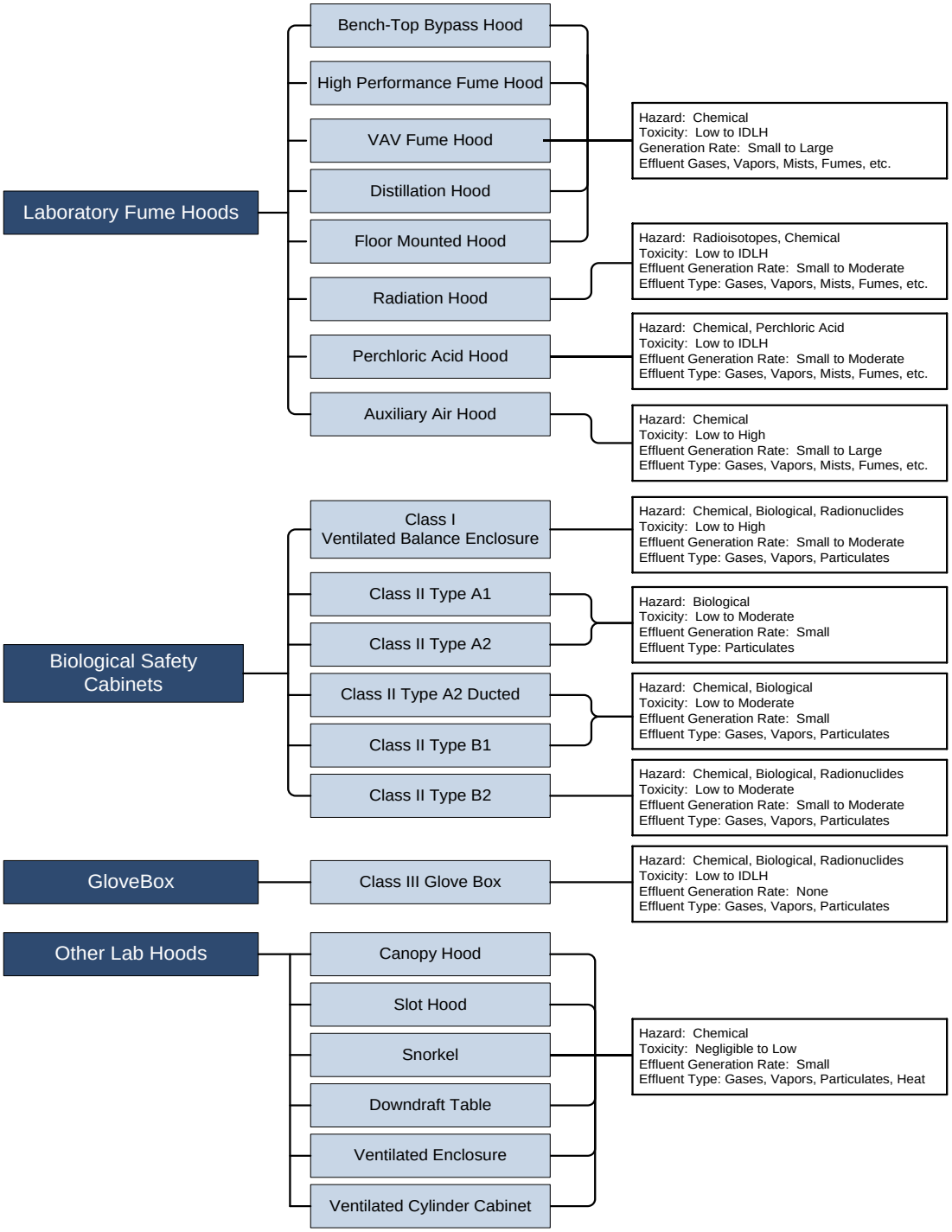

Figure 6-1: Different Containment Devices and Potential Applications
(Source: Exposure Control Technologies Inc., 2011)

6.3.1. Types of Fume Hoods

Fume hoods are available in many different types, sizes, and configurations to accommodate research laboratory procedures and processes. Unlike BSCs that have well-defined classes and types to identify different models, fume hoods are not similarly categorized. Fume hoods are often identified by a description of the size and key components of the design. For example, a common fume hood is a 6-foot, bench-top, bypass fume hood. This fume hood can easily be confused with a 6-foot, bench-top, radiation fume hood that differs only by the design and construction of the internal liner. Furthermore, fume hoods can be described by the type and configuration of the moveable sash such as a 6-foot, bench-top, vertical-sash, bypass fume hood. Figure 6-2 shows the common components of a fume hood.

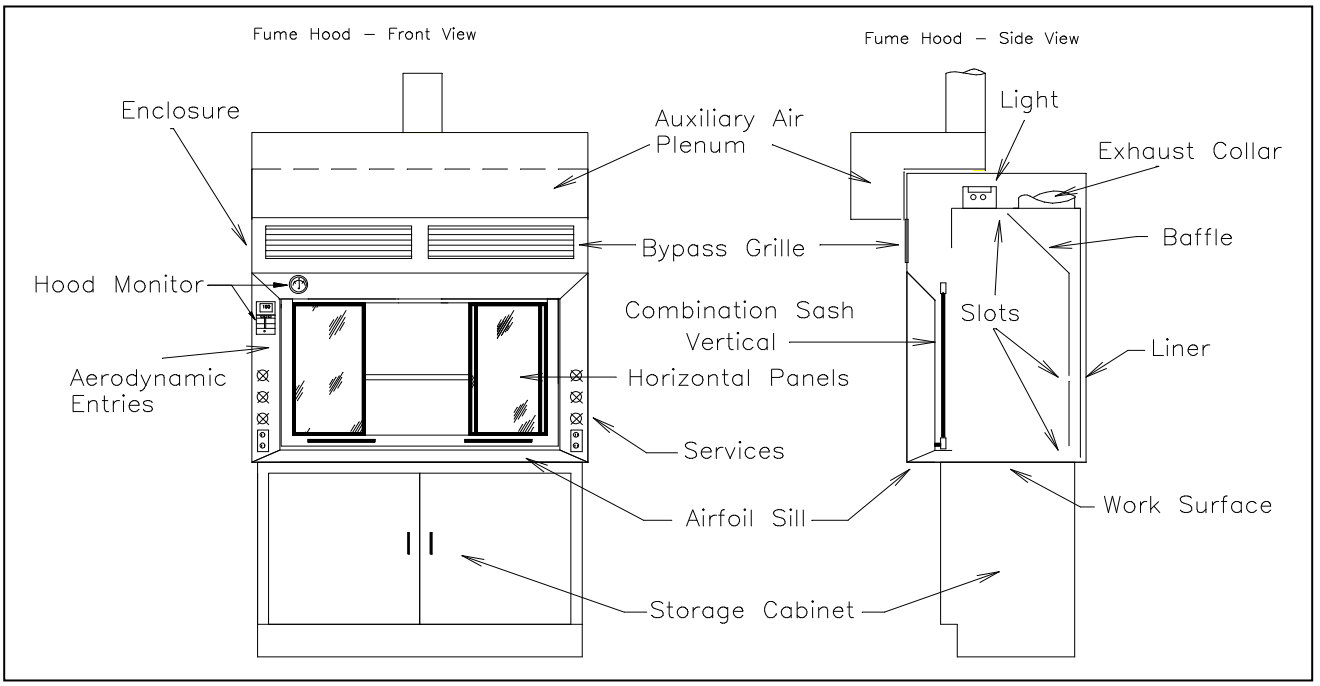

Figure 6-2: Fume Hood Components (Source: ASHRAE 110, Method of Testing Performance of Laboratory Fume Hoods)

The interior dimensions, together with the opening size and design of the fume hood components, are used to determine the flow specifications and resulting ability to provide containment performance. Fume hood size is generally determined by the width of the fume hood opening plus the width of the exterior enclosing panels. It should be noted that the size of the fume hood is not a measure of the sash opening width.

The fume hood must be large enough to accommodate research apparatus and equipment. Typical specifications for the interior depth and height of a bench-top fume hood are a minimum of 24 inches and 48 inches, respectively. According to Appendix A (non-mandatory) of the Code of Federal Regulations (CFR) 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories fume

hood openings should provide at least 2.5 linear feet of space per person for every two people working with hazardous chemicals that require exhaust ventilation.

Additional information on several fume hood styles including constant air volume (CAV), variable air volume (VAV), and specialty fume hoods can be found in Enclosure 6-3.

6.3.2. Fume Hood Operation

Air flow drawn through the opening of a fume hood creates an air barrier at the plane of the sash that minimizes outward leakage of contaminants generated inside the fume hood chamber. A fume hood does not reliably provide absolute chemical containment due to the lack of a physical barrier. Fume hood effectiveness is a function of the direction, velocity, and distribution of the air flow entering through the sash opening, and any effects of turbulence. The operator and procedures performed inside the fume hood also affect containment. The aerodynamics of the fume hood intake and the baffles at the back of the fume hood help control the direction and distribution of air flow through the fume hood opening as well as the capture-efficiency.

6.3.2.a. Leakage of Hazardous Air Contaminants from the Fume Hood

Leakage of hazardous airborne materials from the fume hood can occur at any location across the opening. However, certain areas, including the horizontal and vertical edges of the sash panels and along the vertical edge of the side posts above the horizontal top of the airfoil sill, are more prone to allow escape of hazardous airborne materials. A person standing in the opening of the sash may also create turbulence. Figure 6-3 illustrates the escape of air below the sash and above the airfoil sill using smoke to visualize air flow patterns. The aerodynamic design of the sash handle, airfoil sill, and side posts are the primary factors affecting air flow, distribution, turbulence, and escape of hazardous contaminants at those locations.

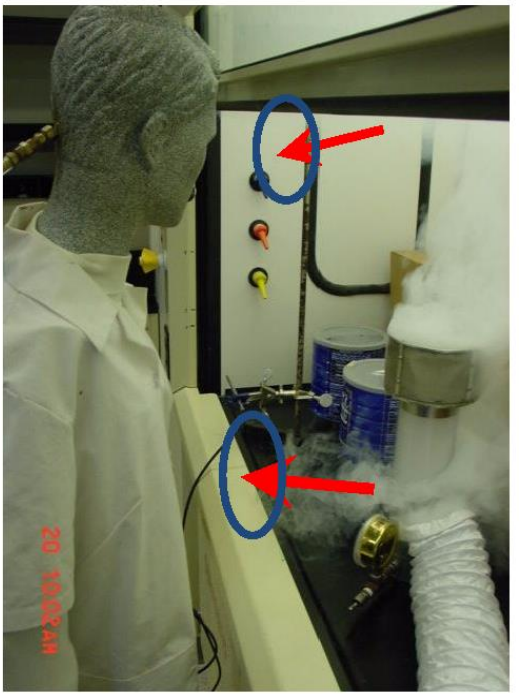

Figure 6-3: Areas Prone to Escape in a Fume Hood
(Source: Exposure Control Technologies Inc., 2011)

Additional factors that affect the variations of face velocities include:

- Air currents in the room (cross drafts from supply diffusers).
- Extreme temperature differences.
- People walking by the fume hood.

6.3.2.b. Sash Opening Configurations

Fume hoods are equipped with moveable sash panels to adjust the opening area. Depending on the design of the fume hood, sashes can consist of single or multiple panels that slide vertically (vertical sash) or horizontally (horizontal sash) to increase or decrease the access opening. Sashes should be configured to provide optimum user protection. A hazard assessment should identify the opening area required for the user to access and safely conduct procedures in the fume hood.

The fume hood opening should be clearly indicated, and a mechanical stop installed to remind the users of the opening restrictions. The vertical sash configuration should allow the user to access the entire width of the fume hood opening, but limit access to the top of the fume hood chamber. Vertical sashes offer fume hood users greater safety by protecting the upper torso from splashes of hazardous chemicals as shown in Figure 6-4. In horizontal sash configurations (Figure 6-5), the user has access to the top of the fume hood chamber but limited access from side to side. Fume hood containment of vapors/gases can be equivalent for either sash configuration. The maximum sash opening should be based on results of performance testing. Operating a fume hood at sash openings

larger than the design opening can result in lower face velocities and the potential for escape of hazardous airborne materials.

Figure 6-4: Fume Hood with a Vertical Sash at Restricted Height Design Opening (Source: Lawrence Berkeley National Laboratory, 2006)

Figure 6-5: Fume Hood with Horizontal Sash Opening
(Source: Lawrence Berkeley National Laboratory, 2006)

6.3.3. Airfoil Sills

All bench-top fume hoods should be equipped with an airfoil sill (Figure 6-6). The airfoil sill streamlines flow into the fume hood over the work surface, reduces air vortex formation (turbulence), and reverses flow along the bottom of the opening.

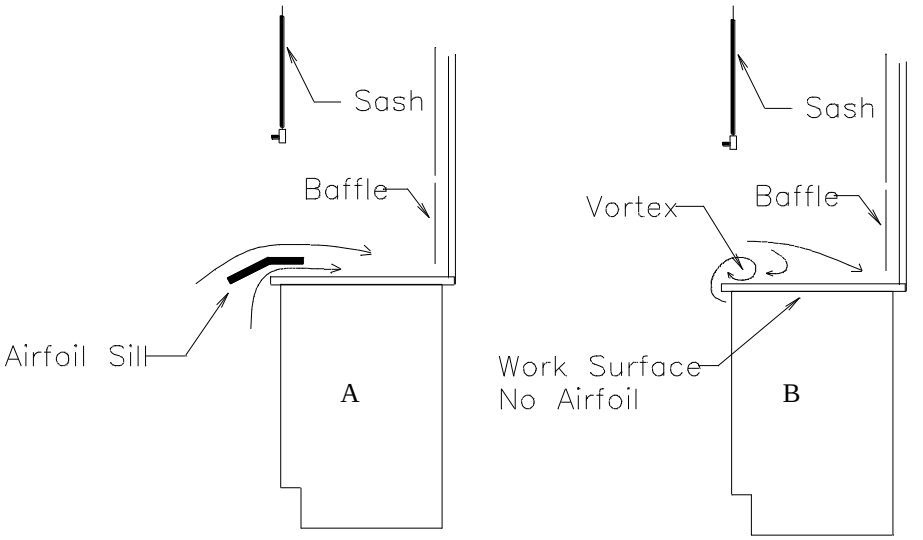

Figure 6-6: Fume Hood Work Surface Diagram Showing Air Flow Patterns With and without Airfoil Sill
(Source: Exposure Control Technologies Inc., 2011)

6.3.4. Baffle Design and Configuration

The design of the baffle and configuration of the capture slots affect the direction and uniformity of air flow through the opening and the capture of airborne materials within the fume hood. Improper baffle and slot configuration can result in escape of contaminants from the fume hood regardless of the average face velocity. The baffles and slots are adjusted to achieve the flow patterns that ensure satisfactory fume hood containment and contaminant removal from the fume hood. Equipment and apparatus in the fume hood can disrupt air-flow patterns, and adjustments of the baffle may be necessary to ensure containment. The baffles should be adjusted by qualified personnel during fume hood commissioning tests and evaluated following installation of equipment and apparatus in the fume hood.

The left diagram in Figure 6-7 presents a side view of the fume hood and illustrates the baffle and slots in the baffle. Baffle panels with adjustable slot widths can change the direction and distribution of air flow through the opening. The fume hood shown in the middle diagram in Figure 6-7 has the top slot open creating an upward flow of air through the opening. Conversely, the diagram on the right in Figure 6-7 shows a downward flow of air through the top of the opening, and increased directional flow across the work surface with the top slot nearly closed.

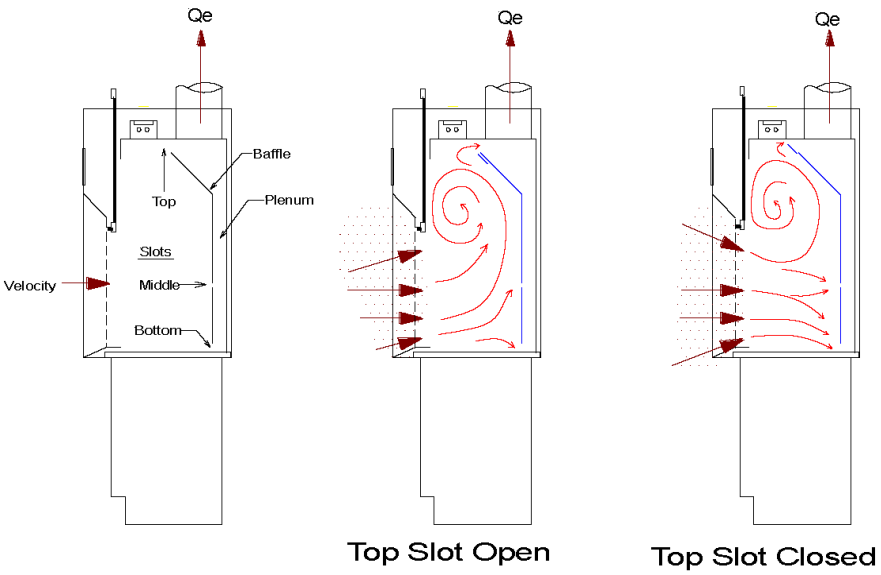

Figure 6-7: Design and Configuration of Baffle Panels and Capture Slots
(Source: Exposure Control Technologies Inc., 2011)

In Figure 6-8, the left photo shows smoke flow in an empty fume hood with the top slot of the baffle fully open. The upward air flow combined with decreased flow across the work surface results in reverse flow and escape over the airfoil sill downstream of the mannequin at the opening. The fume hood pictured on the right of Figure 6-8 shows air flow patterns when the top slot was nearly closed. The closed top slot creates higher air flow capture across the work surface with better fume hood containment at the user position.

Figure 6-8: Fume Hood Showing Reverse Flow and Escape Near Airfoil Sill with Top Slot Fully Open (Left) and Fume Hood Showing Capture at Bottom Slot with Top Slot Closed (Right)
(Source: Exposure Control Technologies Inc., 2011)

6.4. Determining Fume Hood Operating Specifications

The following sections provide guidelines for establishing performance criteria and operating specifications for fume hoods.

6.4.1. Functional Requirements and Performance Parameters

A fume hood must meet the functional requirements and performance criteria defined in Section 6.1.1, Hazard Assessment. In general, a fume hood system should prevent exposure of personnel to hazardous airborne contaminants generated in the fume hood. Tests to evaluate fume hood performance include face velocity measurements, smoke pencil visualization of air flow, or concentration of a tracer gas generated during containment tests. The operating specifications define how the systems operate to provide the given level of performance. Meeting the performance criteria for containment requires operating the fume hood at a specified exhaust flow to achieve the average face velocity at the design sash opening and baffle settings. Performance parameters for each fume hood should be appropriate for the intended function and specified prior to performance testing. Specific parameters can include:

- Operating modes.
- Opening configuration.
- Range of flow and velocity.
- Differential pressure and system static pressure.
- Maximum cross-draft velocities.
- VAV speed of response and flow stability.
- Accuracy.
- Qualitative and quantitative containment requirements.

6.4.2. Operating Modes

A fume hood can have multiple modes of operation to meet changing demands for proper ventilation. Operating modes should be well defined and assigned appropriate performance criteria and operating specifications. The operating modes for a fume hood can be simple or complex depending on the capability of the controls. Simple CAV systems have only one mode of operation wherein the fume hood operates continuously at full air flow regardless of use. More complex VAV control systems enable multiple modes of operation that alter flow depending on the position of the sash or whether someone is standing at the opening. Operating modes for a VAV fume hood equipped with sash sensors and an occupancy detector include:

- Sash open.
- Sash closed.
- Sash open: occupied (person at fume hood opening).
- Sash open: unoccupied (person not at the fume hood opening).

6.4.3. Flow and Velocity Specifications

Air speed measured at the sash plane is referred to as the face velocity. Average face velocity is calculated by averaging the air velocity measurements collected at multiple points across the opening. Air turbulence within the fume hood depends on air flow rate, equipment placement, and fume hood design.

Typical fume hood operating face velocities should be between 80-120 feet per minute (fpm) and should not be less than 90% or greater than 120% of the benchmark velocity based on the toxicity of the chemical used and the equipment set up in the hood. Face velocity should not be lower than 60 fpm as containment is not reliable. Face velocities can be greater than 120 fpm in some applications; however, containment is not significantly improved at higher velocities (greater than 150 fpm). Velocities greater than 150 fpm may cause turbulence, creating a potential for leakage of contaminant outside of the fume hood.

Selecting a face velocity is based on a number of factors including:

- Understanding the hazards, processes, and generation rate of chemical vapors.
- Controlling flammable vapors and ignition sources, lower explosive limit (LEL), and the safety factor (10-25% of the LEL).
- Fume hood design, internal air flow patterns, and mixing factors.

6.4.4. Fume Hood Monitors

All fume hoods should be equipped with a fume hood monitor (Figure 6-9) that indicates flow, pressure, or face velocity, and provides both audible and visual alarms to alert users of improper exhaust flow or low face velocity. The fume hood monitor should be capable of indicating that the air flow is in the design range. Improper air flow or face velocity is high or low by 10%. The accuracy of the monitor must be plus or minus 5% of the measured value, and the calibration of the monitor should be verified on an annual basis.

Figure 6-9: Through-the-Wall Velocity Sensor

(Source: Exposure Control Technologies Inc., 2011)

6.5. Research Laboratory Fume Hood Ventilation Assessment and Testing Principles

According to 29 CFR 1910.1450, research laboratories must ensure proper functioning of fume hood systems, which requires assessment of system design and performance testing.

6.5.1. Fume Hood Operating and Test Criteria

Appropriate operating specifications, based on satisfying the performance criteria, must be established for every fume hood. Specifications are unique to the fume hood system and experimental process. Parameters in specifications include:

- Operating modes.
- Opening configuration.
- Range of air flow and velocity.
- Fume hood static pressure.
- Maximum cross-draft velocities.
- VAV speed of response and flow stability.
- Air flow or pressure monitor accuracy.
- Qualitative and quantitative containment requirements.

Many hoods do not have standardized tests that evaluate performance. Functional tests must be appropriate to accurately evaluate performance and can be obtained under the following conditions:

- “As manufactured” to evaluate the design of the fume hood.
- “As installed” to evaluate the performance of the fume hood under existing research laboratory conditions.
- “As used” to evaluate the effect of equipment or obstructions located in the fume hood during hazardous procedures.

ASHRAE 110 describes procedures for evaluating the operating conditions and performance of the fume hood. Typical tests to evaluate the operating conditions include:

- Face velocity.
- Exhaust flow.
- Fume hood static pressure.
- Cross-draft velocity.
- VAV response and stability.
- Air flow visualization tests using smoke and tracer gas containment.

Periodic inspection of the fume hoods is required to monitor operations. A sample research laboratory fume hood inspection form is available on the U.S. Department of Agriculture (USDA) website.

Enclosure 6-4 includes recommended tests applicable to different fume hood types. Enclosure 6-5 provides research laboratory fume hoods and hazards information.

6.5.2. Test and Maintenance Management

The Research Service, Safety Office, and FMS are responsible for conducting and carrying out procedures for evaluating fume hood performance, reporting problems, and correcting deficiencies. A preventive maintenance plan ensures that the fume hood systems function within operational specifications for the duration of required use. Below are some guidelines for testing and maintenance management:

- Preventive maintenance programs are based on system component (blower motor, impeller condition, belts/pulleys, baffles, etc.) requirements, actual use conditions, and manufacturer recommendations.
- Staff performing maintenance must be appropriately trained and qualified.
- Preventive maintenance procedures and testing must be documented.
- All fume hoods should be tested at least annually.

6.5.3. Reporting and Record Keeping

Test results must be provided to the Research Service, Safety Office, and FMS, and retained in accordance with local policies. Where there are variations from established criteria, the Research Service, Safety Office, and FMS must develop a corrective action plan.

The Subcommittee on Research Safety (SRS) is responsible for ensuring that laboratories are inspected at least annually. Inspections should verify that all fume hoods currently in use have been appropriately certified and are being used correctly. The SRS also verifies that deficiencies are corrected in a timely manner.

The facility should maintain complete records that can be accessed when necessary for each research laboratory ventilation system. Records could include:

- As-built drawings.
- Commissioning report.
- Equipment replacement or modifications.
- Test and balance reports.
- Inspection and routine test reports.
- Periodic performance and operation reports.
- Maintenance logs.
- Reported problems.
- System modifications.

6.6. Work Practices

The following are recommendations for working safely in a fume hood:

- Research laboratory staff needs to be trained on the proper use of and work practices for fume hoods.
- Ensure that the fume hood is functioning properly by checking the continuous monitoring device each time the fume hood is used.
- Ensure that the fume hood has a current certification sticker (with date and certifier name), required sash height, and face velocity measurement at operating sash height.
- Do not use a visibly damaged fume hood (for example if there are missing panels, improperly adjusted baffles, or sashes that fail to hold position).
- Flutter strips are not permitted as continuous monitoring devices.
- Keep exhaust fans on at all times.
- Keep the sash closed as much as possible to maintain a glass barrier between the worker and the chemical source. Do not put your head inside the fume hood, as shown in Figure 6-10.

Figure 6-10: Improper Fume Hood Use
(Source: Exposure Control Technologies Inc., 2011)

- Do not modify fume hoods by adding, removing, or changing any components that affect performance. This includes baffles, sashes, airfoil sills, liners, and exhaust connections.
- Minimize rapid movements in front or inside of fume hoods, such as opening and closing the sash, swift arm and body movements, or pedestrian traffic.
- Equipment should be placed towards the back of the fume hood without blocking the bottom baffle.
- Separate and elevate equipment by using racks or blocks to allow air flow around all equipment.

- When appropriate, a 6-inch gap should be maintained between the plane of the sash (fume hood face) and work conducted inside the sash or panels.
- Do not store flammable chemicals inside fume hoods.
- Store chemicals under fume hoods *only* in approved cabinets.
- Do not use fume hoods for waste disposal, such as evaporation, dumping, and/or treatment.
- Remove all chemicals from the fume hood prior to maintenance activities.
- Label all fume hoods that are out of commission as “not to use”.
- If contractors are used for fume hood certification, the following should be considered:
    - The contractor should have a copy of fume hood inspection and certification criteria.
    - Contractor inspection and certification should be verified by the Contracting Officer’s Representative (COR).
    - Quality control should be initiated to verify contractor performance.

6.7. References and Resources

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7. ANSI/ASHRAE 41.3-1989, Standard Method for Pressure Measurement.
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9. ANSI/AIHA Z9.5, Laboratory Ventilation.

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17. NFPA®45, Fire Protection for Laboratories Using Chemicals.

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19. Sartor, D. (2006). *Taming the fume hoods: A strategic plan to reduce the energy impact of California fume hoods*. Retrieved from http://ateam.lbl.gov/hightech/fumefume hood/doc/Taming%20the%20Fume hoods%2020060316.pdf.

20. Sheet Metal and Air Conditioning Contractors' National Association (1995). *HVAC duct construction standards: Metal and flexible*. Merrifield, VA.

6.8. Enclosures and Fact Sheets

Fact Sheets for Research Laboratory Guidebook

The following fact sheets contain quick-reference information relevant to this chapter:

8.1 General Research Laboratory Ventilation and Fume Hoods

Enclosure 6-1 General Research Laboratory Design Specifications

Enclosure 6-2 Research Laboratory Exhaust Ventilation

Enclosure 6-3 Additional Fume Hood Types and Information

Enclosure 6-4 Recommended Tests for Different Fume Hood Types

Enclosure 6-5 Research Laboratory Fume Hoods and Hazards Information

Biological Safety in Research Laboratories

7.1. Introduction

Biological agents commonly used in research laboratories present a risk of exposure to research workers. The Veterans Health Administration (VHA) Handbook 1200.08, Safety of Personnel Engaged in Research clearly states that individual research laboratories must adhere to Centers for Disease Control and Prevention (CDC) Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th edition and National Institutes of Health (NIH) safety and health guidelines for recombinant deoxyribonucleic acid (rDNA).

A study of clinical and research laboratories (Harding and Byers, 2006) found that 51% of laboratory-acquired infections (LAIs) originated from exposures in research laboratories, with some of the occupationally acquired infections proving fatal. Most laboratory exposures are known to occur at biological safety level (BSL)-2 containment and involve common biological agents. Some common infectious organisms include, but are not limited to:

- *Escherichia coli.*
- Hepatitis B (HBV).
- Hepatitis C.
- Human immunodeficiency virus (HIV).
- *Mycobacterium tuberculosis.*
- *Neisseria meningitides.*
- *Salmonella spp.*
- *Shigella spp.*

7.2. VHA Biological Safety Program and Policy

VHA Handbook 1200.08 requires every Department of Veterans Affairs (VA) Research Program in which research involving hazards is performed to establish and implement a research-specific safety plan. For research programs in which work with biological hazards is conducted, the safety plan must include biological safety practices and procedures. Additionally, research laboratories that involve work in BSL-3 containment are required to maintain a separate biological safety research laboratory manual that includes specific standard operating procedures (SOPs) and emergency procedures for that laboratory. The requirement also exists for manuals to be reviewed and updated annually by the Subcommittee on Research Safety (SRS). Additional information can be found on the VHA Research and Development website

7.2.1. Research Laboratory Manuals

A research laboratory manual should include provisions for engineering controls, work practice controls or administrative controls, standardized procedures, and personal protective equipment (PPE) necessary to protect workers from potential exposures in research laboratories. These should include mechanisms to minimize or eliminate exposures to biological hazards and coordination with the Employee Occupational Health unit to provide workers with immunizations and/or post-exposure treatment, if available. Additionally, all research laboratory workers must be aware of and utilize universal precautions in the handling of biological materials that may be contaminated with bloodborne pathogens. These procedures must follow Code of Federal Regulations (CFR) 29 CFR 1910.1030, Bloodborne Pathogens.

7.2.2. Biohazard Emergency Procedures

Emergency procedures must be in place for biohazardous spills and post-exposure protocols. Spills of biohazardous material must be dealt with promptly by an individual properly trained to manage such spills. An example of an SOP for dealing with a biohazardous spill can be found in Enclosure 7-1, Sample Biological Spill Response Procedures.

Post-exposure prophylaxis guidelines for bloodborne pathogens are covered in 29 CFR 1910.1030. Anyone exposed to biological hazards in the research laboratory setting should report to an emergency department and/or Employee Occupational Health immediately for evaluation and possible treatment.

7.2.3. Biosecurity

The objectives of biosecurity are focused primarily on administrative controls and physical security to prevent loss, theft, or misuse of microorganisms, biological materials, and research-related information. Biosecurity differs from biosafety in that the goal of a biosecurity program is to protect against the mishandling of pathogens by individuals with potentially dangerous or criminal intentions, while a biosafety program is designed to reduce or eliminate exposure of research laboratory workers and the environment to potentially hazardous agents. Biosecurity is accomplished by limiting access to facilities, research materials, and information to authorized individuals. Appendix E, Research Laboratory Security and Emergency Response for Microbiological and Biomedical Laboratories, from VHA Handbook 1200.08, includes the VHA policy on biosecurity and emergency response. Heightened security requirements apply to research laboratories in which work is conducted with select agents and toxins or that involves high-containment (BSL-3).

The five step process for a biosecurity risk assessment provided in the BMBL, 5th edition, is as follows:

1. Identify and prioritize biological materials.
2. Identify and prioritize the threat to biological materials.
3. Analyze the risk of specific security scenarios.

4. Develop an overall risk management program.
5. Re-evaluate the institution's risk posture and protection objectives.

VHA Handbooks 1200.06, Control of Hazardous Agents in VA Research Laboratories, and 1200.08, provide security guidelines for all research laboratories. The basic principles are:

- Prepare a research-specific security plan and review it annually.
- Verify the status of research workers with without compensation (WOC) status or VISA status annually.
- Perform background and security clearances on all personnel authorized to access research areas and verify the continued need for personnel access on a semi-annual basis.
- Restrict access to research areas by means of key-card access or a state-of-the-art security system that includes permanent/dated records of persons entering and times of entrance.
- Adhere to the requirement for the Associate Chief of Staff (ACOS) for Research and Development (R&D), or designee, to review all access records weekly and document any findings.
- Establish a procedure for reporting incidents involving research laboratory security.
- Ensure provisions for conducting annual drills to test the effectiveness of security plans and for conducting annual multi-disciplinary vulnerability assessments (MDVAs):
    - Security risks, including high-risk areas, sensitive materials, and any other potential physical security issues, are evaluated.
    - Results of the drills and MDVAs are reported to the SRS and the R&D Committee.
    - Corrective actions are implemented to assess any vulnerability identified.
    - The multi-disciplinary team includes, at a minimum, representatives of the Research Service, Police Service, and the facility Safety Office.

Research laboratory workers are required to know who is in the research laboratory area at all times. Workers, guests, visitors, repair personnel, and vendors must wear identification badges. Workers should politely question any person without an escort or proper identification and notify the Police Service or a member of the Research Service immediately of any suspicious individuals or activity. In addition, research laboratory workers must be aware of what materials (hazardous wastes, equipment, sensitive data, cultures, etc.) are being removed

from the research laboratory area. VHA policies, as well as site-specific institutional policies, that govern access control to the research laboratory must be enforced. Section 7.8, Work Practices and Controls, discusses these requirements in detail.

7.3. BSLs and Risk Groups

7.3.1. Biological Safety Levels

There are four BSLs of containment from least (BSL-1) to most hazardous (BSL-4). The term containment refers to the mechanisms used to manage infectious organisms in the research laboratory setting to minimize the risk(s) of exposure, both to workers and the environment. The main risk criteria used to define BSLs are the infectivity of the organism, the severity of the disease(s) caused by the organism, the likelihood of disease transmission, the availability of effective immunizations or treatments, and the work being conducted with the organism. The four BSLs define the safety requirements, standard microbiological practices, any special practices or procedures, required protective equipment, and facility safeguards for the corresponding level of risk associated with a particular organism. Standard microbiological practices should be common to all research laboratories. However, special practices and procedures may be needed to enhance worker safety and environmental protection and to address the risk of handling more hazardous organisms. The BMBL, 5th edition, has identified combinations of standards, special microbiological practices, safety equipment, and facility safeguards that should be used to prevent exposure and/or release of hazardous organisms. Additional information on BSLs can be found in the BMBL, 5th edition, Table 2: Summary of Recommended Biosafety Levels for Infectious Agents.

Standard microbiological practices, including prohibition of mouth pipetting, eating, drinking, and applying cosmetics in the research laboratory; good housekeeping techniques; and washing hands after working with potentially hazardous materials, are important regardless of the research laboratory type and should be exercised at all BSLs. Standard microbiological practices have some commonalities with the research laboratory practices found in Chapter 5, Chemical Safety in Research Laboratories. PPE requirements must be followed with more stringent requirements as the BSL increases.

Universal precautions must be followed when working with contaminated sharp materials. Whenever practical, Research Laboratory Supervisors should adopt improved engineering controls and work practices or administrative controls that reduce risk of sharps injuries. Policies for the safe handling of sharps, such as needles, scalpels, pipettes, and broken glassware, must be developed and implemented. Needles must not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated by hand before disposal. Used disposable needles and syringes must be carefully placed in conveniently-located, puncture-resistant containers used for sharps disposal. Non-disposable

sharps must be placed in a hard-walled, leak-proof container for transportation to a processing area for decontamination.

7.3.1.a. Biological Safety Level 1 (BSL-1)

BSL-1 research laboratories are suitable for working with organisms that have been well-characterized and are not known to cause disease or to pose serious exposure risks to research laboratory workers or the environment. Work with BSL-1 organisms requires standard microbiological practices sufficient to minimize associated risks and is typically conducted on open bench tops. Special containment equipment or facility containment design features are generally not required in BSL-1 research laboratories unless determined appropriate based on a risk assessment. Research laboratory workers must have specific training in the procedures conducted in the research laboratory and must be supervised by a scientist with training in microbiology or a related science. BSL-1 facility requirements include research laboratory doors for access control, a sink for hand washing, and windows fitted with screens if they open to the exterior.

7.3.1.b. Biological Safety Level 2 (BSL-2)

Requirements for BSL-2 research laboratories build on the specifications for BSL-1. BSL-2 research laboratories are suitable for working with organisms that pose moderate hazards to both personnel and the environment. Differences between BSL-1 and BSL-2 include the requirement for all personnel to be trained specifically in the handling of biological agents, for access to the research laboratory to be restricted when work is in progress, and for work that may generate infectious aerosols or splashing to be performed in a Class II biological safety cabinet (BSC) or similar containment device. Detailed information about BSCs can be found in Section 7.15.

BSL-2 special practices require all persons entering the research laboratory to be advised of the potential hazards and to meet specific entry and exit requirements. Research laboratory workers must be provided medical surveillance and offered appropriate immunizations for agents handled, or potentially present, in the research laboratory. The Principal Investigator or Research Laboratory Supervisor must ensure that research laboratory workers demonstrate proficiency in microbiological practices before working with BSL-2 agents. BSL-2 research laboratory doors should be self-closing and have locks in accordance with local policies. Research laboratories must have a sink available for hand washing.

BSL-2 barriers and safety equipment, including properly maintained BSCs, appropriate PPE, and other physical containment devices, must be used whenever procedures with a potential for creating infectious aerosols or splashes are conducted. Aerosol and droplet-producing operations include pipetting, centrifuging, grinding, blending, shaking, mixing, sonicating, opening containers of infectious materials, animal inoculations, and harvesting infected tissues from animals or eggs.

BSCs should be installed away from doors and air-supply registers. BSCs with a properly maintained high-efficiency particulate air (HEPA) exhaust filter can recirculate filtered air back into the research laboratory or be vented directly to the outside. BSCs are certified annually (semi-annually when working with airborne pathogens). Waste vacuum lines and pumps should be protected from contamination when using for aspiration of biohazardous material. A disinfectant trap, overflow flask, and a hydrophobic filter should be installed to prevent fluid and aerosol contamination of central vacuum systems or vacuum pumps. The filter will also prevent microorganisms from being exhausted by a vacuum pump into the environment.

Work surfaces must be decontaminated with a suitable disinfectant at the completion of work, as well as after any splash or spill. Similarly, all cultures, stocks, and other potentially infectious materials must be decontaminated before disposal using an effective method (disinfectant, autoclave, etc.). Materials to be decontaminated outside of the immediate research laboratory, but within the facility, must be placed in a durable, leak-proof container and secured for transportation. Methods for decontaminating research laboratory equipment should be described in the facility's Research Laboratory Biosafety Manual. Equipment must be decontaminated after potential contamination and before repair, maintenance, or removal from the research laboratory. A form for declaring equipment to be free of all hazards is provided in Enclosure 7-2.

Spills involving infectious materials must be contained, decontaminated, and cleaned up by properly trained staff equipped to work with infectious materials. This action must take place as soon as possible after a spill occurs. Any potential exposure to infectious materials must be immediately evaluated and treated according to procedures described in the facility's Research Laboratory Biosafety Manual. All such incidents must be reported to the Principal Investigator and Research Laboratory Supervisor. Medical evaluation, surveillance, and treatment should be provided as appropriate for the agent, and associated records must be maintained.

7.3.1.c. Biological Safety Level 2 with Enhanced Practices (BSL-2 E)

BSL-2 E was formally referred to as BSL-2 Plus in the 4th edition of the BMBL. This designation was developed to allow work with slightly more hazardous organisms and procedures in a BSL-2 environment using enhanced procedures and work practices that exceed standard BSL-2 requirements, including appropriate safety equipment (BSCs, safety centrifuge cups, etc.). This designation is no longer used in the VA. Research laboratories that need enhanced safety practices should be upgraded to BSL-3.

7.3.1.d. Biological Safety Level 3 (BSL-3)

Requirements for BSL-3 research laboratories follow all of the specifications for BSL-2, but the additional required practices and controls are more stringent because BSL-3 organisms pose greater hazards. BSL-3 research laboratories are

designed to support work with agents that are characterized by their potential to cause serious or even lethal disease through inhalation exposure. Research laboratory workers in a BSL-3 environment must receive specific training in handling pathogenic and potentially lethal agents. Research laboratory workers must be supervised by scientists competent in handling infectious agents and in performing associated procedures. Additionally, a BSL-3 Research Laboratory Biosafety Manual must be developed and made accessible to research laboratory workers. The Principal Investigator must ensure that research laboratory workers demonstrate proficiency in standard and special microbiological practices before working with BSL-3 agents.

BSL-3 research laboratories have special design, construction, and commissioning requirements (performance and operation) that must be verified and documented prior to start-up. Performance and operations must be re-verified and documented at least annually.

A dedicated air ventilation system is required and must provide sustained, continuous, inward directional air flow from clean areas into the research laboratory toward potentially contaminated areas. This keeps any hazardous bioaerosol that may escape a BSC contained within the BSL-3 research laboratory. The research laboratory must be designed such that under power failure, the air flow will not be reversed. Research laboratory workers must be able to verify directional air flow. A visual monitoring device that confirms ventilation operation must be provided at the research laboratory entrance. Audible and/or visual alarms should indicate when air flow is disrupted.

BSL-3 primary containment requirements include the use of a Class II or Class III BSC or other approved physical-containment devices, such as a centrifuge, safety cup, or sealed rotors, for all procedures involving manipulations of open vials or vessels with the potential for creating aerosols or droplets of infectious materials. Work with agents that require BSL-3 containment is not permitted on an open bench. Protective research laboratory clothing with a solid front, such as tie-back or wrap-around gowns, scrub suits, or research laboratory coveralls, must be worn by workers when in the research laboratory.

BSL-3 secondary containment is used to separate the research laboratory from areas that are open to unrestricted traffic flow within the building. Access to the research laboratory must be restricted by a series of two self-closing doors, with a clothing change room (anteroom) included in the passageway between the doors. Some newer research laboratory buildings may have a series of interlocks that will not allow the door into the research laboratory to open until the outer door has completely closed and latched. Windows in BSL-3 research laboratories must be sealed.

Equipment that may produce infectious aerosols must be contained in devices that exhaust air through HEPA filtration. These HEPA filters must be tested,

replaced per manufacturer instructions (at least annually), and monitored for pressure drop or minimum air flow (filter loading).

7.3.1.e. Biological Safety Level 4 (BSL-4)

Under current VHA research policy, *VHA researchers are not permitted to perform VA research with organisms that require BSL-4 containment*; this applies both to work performed on VA property and at affiliates. BSL-4 research laboratories are designed to support work with dangerous/exotic agents that pose high individual risk of aerosol-transmitted research laboratory infections that are frequently fatal, and for which there are no immunizations or treatments. Agents with unknown risk of transmission require BSL-4 designation.

7.3.1.f. Determining a BSL

There are several steps in determining a BSL. The first step is to identify the hazards of the agent and to conduct a risk assessment on attributes such as the ability to infect, susceptibility to the human host, available preventive and/or therapeutic measures, and related risk group assignment information. The second step is to identify hazards related to research laboratory procedures, including agent concentration, the likelihood of aerosol or droplet generation, and equipment required. The third step is to review the risk assessment with a biological safety professional, subject matter expert, and the SRS.

After determining the BSL, select precautions indicated by the risk assessment. Staff should be evaluated for proficiency with safety and equipment practices and procedures.

7.3.1.g. Risk Groups

The risk group classification of an organism is based on its hazardous characteristics, including the ability to cause disease in a human or animal host, the severity of the disease, as well as any preventive measures and effective treatments available for the disease. The World Health Organization (WHO)-recommended risk group classifications, which are the four general risk groups (Risk Group 1 to 4) based on the hazardous characteristics of an organism and the route of transmission of the natural disease, are outlined in the BMBL, 5th edition. The NIH Guidelines established a similar classification and assigned organisms into four risk groups based on associated hazards. The descriptions of both WHO and NIH risk classifications are presented in the BMBL, 5th edition, Table 1: Classification of Infectious Microorganisms by Risk Group. It is important to note that while risk group assignments are similar to BSLs, the two designations are not equivalent, and a risk assessment is required to determine the association between risk group and BSL for a given organism.

7.4. Routes of Exposure

Infectious material may be transmitted by one of the following four methods:

- Direct Contact: In this case, the entry point for infectious material is contact with non-intact skin, eyes, or mucosal tissue.

- Inhalation: Inhalation exposure typically occurs when an aerosol or fine droplets of infectious material is generated. Many common research laboratory procedures, such as centrifuging, opening capped tubes, sonication, vortexing, or expelling material from a pipette tip, can result in the generation of an aerosol or fine droplets.

- Ingestion: Ingestion of infectious materials can occur as the result of poor personal hygiene, improper research laboratory practice(s), or by hand to mouth contact.

- Injection: Injection could occur during animal injections or during the transfer of material using a needle and syringe or any sharp object that could puncture the skin and transfer infectious materials. Injection incidents have also occurred when working with glass pipettes.

7.5. Medical Surveillance

Research laboratory workers may want to participate in a voluntary medical surveillance program that includes a health screening and, in some cases, periodic medical examinations by an Employee Occupational Health professional. The screenings provide an initial baseline that can be used to assess the research worker's risk and monitor future health status with respect to potential occupational exposures. Health status can impact susceptibility to infection, ability to receive immunizations, or effectiveness of other prophylactic measures. It is a good practice to evaluate immune competence and conditions that may present a predisposition to infection for all research laboratory workers.

All exposure incidents must be reported to the Principal Investigator, Research Laboratory Supervisor, and the SRS. Medical evaluation, surveillance, and treatment should be provided and appropriate records maintained. Occupational exposures must be recorded in the Automated Safety Incident Surveillance and Tracking System (ASISTS). Pursuant to the requirements of 29 CFR 1910.1020, Access to Employee Exposure and Medical Records, all exposure records must be kept for at least the duration of employment plus 30 years.

Additionally, the SRS must evaluate the exposure and determine if it must be reported to the Office of Research Oversight.

7.6. Biological Safety Risk Assessment

The Biological Safety Risk Assessment is a tool that attempts to account for as many hazards associated with experimental research laboratory procedures as possible. A research laboratory in which work with biological agents is conducted must have established provisions to manage risks to research laboratory workers and to the surrounding community. The biological safety risk assessment process involves the evaluation of intrinsic hazards and available controls such as engineering controls, work practices or administrative controls, and the use of PPE. Most biological safety risk assessments are based on risk group classifications, but the results are often subjective and variable due to the nature

of the parameters. The descriptions of WHO and NIH risk classifications are presented in the BMBL, 5th edition, Table 1: Classification of Infectious Microorganisms by Risk Group.

The Principal Investigator bears the primary responsibility of ensuring that risk assessments are conducted; however, the SRS, other relevant research oversight committees (Institutional Animal Care and Use Committee, Institutional Review Board, Institutional Biosafety Committee), infection prevention professionals, and safety staff should also be involved in the process. As a dynamic process, risk assessments are agent-specific and should be updated as the project evolves and new factors, such as research laboratory workers, biological agents, or new procedures, are introduced.

The biological safety risk assessment involves five basic steps:

1. Identification of the biohazards (risk of the agent).
2. Prioritization of risks based on potential harmful effects for research laboratory workers, the community, and the environment.
3. Identification of the safety controls (containment) required to conduct work safely.
4. Establishment of SOPs and required training.
5. Continual evaluation of research laboratory procedures, containment, and staff competency.

The Principal Investigator should use the risk assessment to evaluate the training and competency of the research laboratory workers who handle the pathogens or perform procedures and to inform personnel of the hazards associated with working with potentially infectious agents. The assessment is the basis for establishing training on safety measures, equipment, and required PPE. The training of research staff, their demonstrated competency, and compliance with work operations helps to minimize exposure potential.

The aspects for risk assessments are correlated and influence the risk or level of controls needed to mitigate potential hazards. The interaction of the agent, research laboratory workers, and environment defines the basic biological safety risk. The risk assessment results should account for numerous parameters including:

- Route of transmission: Inhalation (most significant route), inoculation, ingestion, or skin or mucous membrane exposure.

- Risk group:

    - Pathogenicity: The ability of an agent to cause disease.
    - Virulence: The magnitude or degree of disease.
    - Infectious dose: The dose required to cause infection.
    - Concentration: The number of infectious organisms per unit volume.

  - Agent stability: Survival in environment or spore formation.
  - Treatment and prophylaxis: Availability of immunizations and/or therapeutic treatment.

- Management oversight:

  - Research laboratory biosafety manuals.
  - Plans for incident response (i.e., spills, equipment failure, medical emergencies).
  - Compliance with operating procedures.
  - Inventory and recordkeeping.
  - Medical surveillance.
  - Staff training and skill level.

- Hazard vulnerability assessment: Natural disasters, severe weather, and HVAC redundancy and reliability.

- Personnel health status: Medical conditions, immunocompetence, age, immunizations, fatigue.

7.7. Personnel Training

The Principal Investigator and Research Laboratory Supervisor are responsible for ensuring that all staff members who work in their areas are appropriately trained regarding their responsibilities, the precautions needed to prevent exposures, and exposure evaluation. According to 29 CFR 1910.1030(g), research laboratory workers who have not demonstrated proficiency in handling pathogens must be assigned a progression of work activity until competency is verified. Training must be provided whenever there are changes in procedures, policies, or individual worker health status.

7.8. Work Practices and Controls

VHA Handbook 1200.08 requires compliance with CDC and NIH safety and health guidelines. Containment is essential to the safe handling of potentially infectious material. A key component of effective containment is adherence to standard microbiological practices, which are required at all BSLs. Unless proper equipment and techniques are in place and followed, many common research laboratory procedures could result in an occupational exposure. The technical expertise of the Principal Investigator and research laboratory workers, as well as engineering controls and PPE, are critical when manipulating potentially biohazardous material.

7.8.1. Safe Personal Practices

Eating, drinking, smoking, handling contact lenses, applying cosmetics, and mouth pipetting are not permitted in research laboratory areas. Food intended for human consumption must be stored outside the research laboratory in designated areas.

Individuals must wash their hands after working with potentially hazardous materials, whenever gloves are removed, and before leaving the research laboratory. VHA Directive 1131, Management of Infectious Diseseases and Infection Prevention and Control Programs, provides VHA policies for hand washing. Although this directive was created for the clinical environment, hand washing techniques and policies referenced therein are also applicable to the research laboratory environment. Under some circumstances, alcohol-based hand sanitizers may be an acceptable alternative to hand washing.

7.8.1.a. Aerosols

Of the four routes of exposure discussed in Section 7.4, Routes of Exposure, inhalation is of particular concern. Typically with a splash or injection, the individual is immediately aware of the exposure and can take the proper steps to reduce the risk of infection. However, since aerosols are not usually visible or felt on the skin, exposure can go unnoticed.

Certain equipment may require HEPA filtration or use in a BSC because their use can cause aerosolization. Proven sources of aerosols include:

- Vortex mixers.
- Pipettors.
- Sonicators.
- Blenders.
- Grinders.
- Lyophilizers.
- Centrifuges.
- Scraping solid cultures.

Potentially infectious material should never be centrifuged in uncapped tubes. If the worker suspects that a tube has broken during centrifugation, the centrifuge lid should not be opened until any aerosols that may have been generated are allowed to settle. A 15-30 minute wait is generally considered to be sufficient depending on the organism. If centrifuge safety caps (Figure 7-1) are in use, the aerosols will be contained. The centrifuge bucket should be placed in a BSC prior to opening.

Figure 7-1: Centrifuge Safety Caps Installed Over Samples
(Source: University of Texas, Austin, 2011)

Vortexing is a common research laboratory procedure used to re-suspend cells or mix materials. Although the amount of aerosol produced is less than during centrifugation, tubes containing biohazardous material must be capped during vortexing.

Forcefully expelling material from a pipette can also result in the generation of aerosols. Drips from improperly attached tips and contamination of the mechanical device are additional concerns.

7.8.1.b. Splashes

Protective eyewear or a protective splash shield should be used whenever there is a potential for a splash or splatter, such as during the pouring or transfer of infectious material outside a BSC.

7.8.2. Pipetting

A manual pipettor or electronic pipetting device (Figure 7-2) must be employed when pipetting. Plastic tips and disposable barrels used with pipettors should be disposed of in rigid biohazard containers.

Figure 7-2: Electronic Pipetting Device (Source: John Morris Scientific, 2011)

7.9. Sharps

Sharps include objects that can cause a puncture or laceration, such as needles, scalpels, pipettes, and broken glass. In addition to the potential for physical injuries, occupational exposures may occur from sharps that are contaminated with biological agents and chemicals. Therefore, caution must be used when handling and disposing of sharps. Disposal must be in containers that are leak-proof, puncture-resistant, and labeled as biohazardous.

Broken glassware must not be handled directly and should be removed using a brush and dustpan, tongs, or forceps, and disposed of in a puncture-proof double-lined container. If the glass is not contaminated, disposal in a cardboard box specifically designed and labeled for glassware may be used. Contaminated broken glass must be decontaminated or disposed of in a manner to prevent the spread of contamination. Plasticware should be used in place of glassware whenever possible. Engineered safety devices must be evaluated annually to see if improved devices are available as replacements.

Details regarding contaminated sharps are discussed in 29 CFR 1910.1030.

7.9.1. Needle Stick Prevention Program

VHA policy requires that contaminated needles and other contaminated sharps not be bent, recapped, or removed. Shearing or breaking of contaminated needles is prohibited. If the needle or sharp instrument is *reusable*, it must be placed in a rigid puncture-resistant, leak-proof, and properly-identified container until it can be decontaminated and reprocessed. All *disposable* sharps must be placed in a rigid leak-proof, biohazard-labeled container. These containers are usually called sharps containers (Figure 7-3).

Figure 7-3: Sharps Containers (Source: Princeton University, 2008)

Sharps containers that are an appropriate size for the work location should be selected and positioned so that the opening is visible to research laboratory workers. Sharps containers should remain covered unless in use and stabilized to minimize the potential for tipping and spilling the contents. The contents of a sharps container should not exceed the 3/4 line and, when full, must be closed with a locking mechanism that will not allow re-opening. If outside contamination occurs, the primary container should be placed within a second container that prevents leakage during handling, processing, storage, transportation, or shipping. The secondary container must also be labeled according to stated requirements and color-coded according to local procedures.

7.10. Working with Bloodborne Pathogens

29 CFR 1910.1030 covers all employees who could reasonably become infected as a result of contact with blood and other potentially infectious materials as the result of performing their job duties. The standard defines universal precautions as an approach to infection prevention. According to this concept, all human blood and certain human body fluids are to be managed as if known to contain HBV, HIV, or other bloodborne pathogens. After collection, specimens of blood or other potentially infectious materials should be placed in a secondary container that prevents leakage during handling, processing, storage, transportation, or shipping. Additional information on infectious bloodborne diseases is available from the National Institute for Occupational Safety and Health (NIOSH).

Research laboratories used for the experimentation or manipulation of HBV and HIV have additional requirements. Experience with human pathogens or tissue culture is required and proficiency must be shown in standard microbiological practices and other research laboratory techniques prior to working with these pathogens. If the employee has no prior experience, the employer must provide training. The employee is not permitted to begin work with these materials until training is complete and proficiency is demonstrated.

Work with these potentially infectious materials must be completed in a BSC or other physical containment device. Non-disposable PPE must be decontaminated before being taken from the research laboratory. All waste from work areas must either be incinerated or inactivated before disposal. The use of sharps should be avoided or limited to the use of sharps or devices that have been engineered for safety. Management of spills is covered in Section 7.14.2, Spill Clean Up.

7.10.1. Biohazard Signs

A biohazard sign must be posted at the entrance to the research laboratory when infectious agents are present. The sign must include the name and phone number of the Principal Investigator and/or the Research Laboratory Supervisor or other appropriate emergency contact, the BSL of the research laboratory, special requirements for entering the area, and the biohazard warning symbol. Specific agent information should be posted in accordance with local policies. Figure 7-4 shows two examples of biological safety signs.

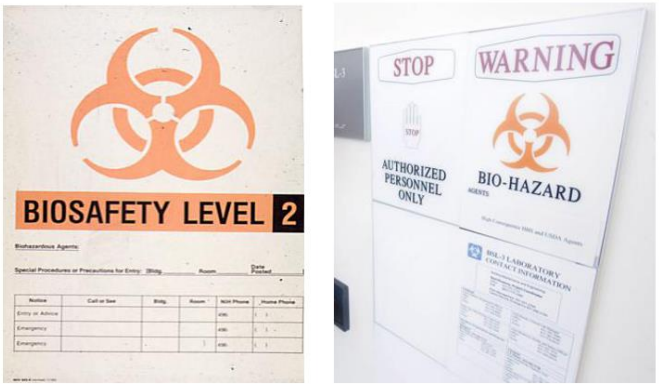

Figure 7-4: Biological Safety Signs

7.10.2. Hazard Communication Requirements

In accordance with 29 CFR 1910.1030, any containers used for infectious waste, transportation of infectious materials, or storage of infectious materials must be labeled with a characteristic biohazard warning label. The label must be affixed so that it is readily visible and cannot be easily removed. The background color of the label must be either fluorescent orange or orange-red, and the icon and warning must be printed in a distinct contrasting color (see Figure 7-5).

Figure 7-5: Biohazard Label (Source: OSHA, 2011)

A biohazard label must also be placed on any equipment, refrigerator, or freezer that contains infectious material. Information indicating the potentially-infectious contents may be included on the equipment label. A biohazard label is not required on equipment or infectious waste that has been decontaminated. The Principal Investigator or Research Laboratory Supervisor must guarantee that items removed from the primary storage containers remain identified as biohazards when used in the research laboratory.

Red bags or red containers can be used only for infectious material storage, transportation, or disposal. The Principal Investigator or Research Laboratory Supervisor must ensure that all research laboratory workers understand the color code system. Infectious waste removed from the research laboratory must be easily identifiable. As a best practice, the biohazard warning label can be printed on red bags or affixed to red containers. Individual containers of infectious materials do not need biohazard labels if they are placed in a labeled container.

7.11. Biohazardous Waste

When dealing with biohazardous waste, infection control and leakage containment are key concerns. Labeling, sterilization, and decontamination procedures must be developed for the handling and storage of biohazardous waste. BSL-1 and BSL-2 biohazards must be disposed of in accordance with federal, state, and local regulations, after appropriate decontamination in the research laboratory, elsewhere at the facility, or at a properly licensed off-site vendor location. BSL-3 biohazards must be decontaminated in the research facility, preferably in the laboratory.

Biohazardous wastes should be disposed of in appropriately-labeled containers (such as bags or rigid containers) that remain closed and upright until removed from the research laboratory. Wastes are collected at the site of generation and then moved into a designated collection/storage area until they are picked up for disinfection and/or disposal. Storage areas for sealed biohazardous containers should be secure and easy to clean.

If biohazardous waste is incinerated on site, the Environmental Protection Agency (EPA) requirements related to air emissions apply. Additional information on the EPA requirements can be found online at: http://www.epa.gov/ttn/atw/129/hmiwi/rihmiwi.html.

7.12. PPE

PPE including, but not limited to, gloves, gowns, laboratory coats, respiratory protection, and face shields or other eye protection, must be readily accessible in appropriate sizes. Goggles, safety glasses, face shields, or other face and eye protection devices should be worn when there is a risk of splash, spatter, or droplets. Contact lenses or prescription glasses are not considered eye protection and must be accompanied by appropriate eye protection.

Protective laboratory coats or gowns must be worn while working with biohazardous materials. Impervious aprons or laboratory coats should be worn in areas where there is a high likelihood of liquid contamination. Laboratory coats are not to be worn outside of research laboratories and must not be taken home. There should be provisions for non-disposable laboratory coats to be laundered at the facility. It should be noted that laboratory coats have a life expectancy determined by the coat material, number of washings, amount of wear, and possible exposure to chemicals.

Gloves should be worn to protect against contact with biohazardous materials. Nitrile, vinyl, and neoprene gloves are preferred due to possible latex allergies. If hazardous chemicals are also in use, the correct glove material choice must be made. Information about glove selection can be found in Chapter 5, Chemical Safety in Research Laboratories.

Based on a risk assessment, double gloves may be required to reduce the potential for penetration of biohazardous materials. Gloves must be changed when contaminated or damaged in any way, and disposable gloves should not be washed or reused. Research laboratory workers should wash their hands after removing gloves. Contaminated gloves cannot be disposed in the regular trash; local procedures for disposal of contaminated waste must be followed. Sleeve protectors may be necessary during high-risk BSC manipulations. Skin rashes or defects can become irritated by wearing PPE, and sensitive areas should be covered or otherwise protected prior to donning gloves.

Use of respiratory protection should be based on a risk assessment. Some activities, such as working with toxic or highly-infectious biological materials, may *require* the use of a respirator that is appropriate for the type of hazard involved. 29 CFR 1019.134, Respiratory Protection, requires a facility Respiratory Protection Program to be implemented when respirator use is required. This includes medical evaluation, training, and fit testing. An N-95 filtering face piece or higher-protection respirator should be used. Further information on respiratory protection programs is available in the VHA Industrial Hygiene Guidebook. Dust

masks and surgical masks are not acceptable respiratory protection devices unless the masks are NIOSH-approved.

When respirator use is not required, 29 CFR 1910.134, Appendix D, Information for Employees Using Respirators When Not Required Under the Standard, must be provided to employees who *elect* to wear a respirator as an additional precaution.

7.13. Housekeeping

The worksite is to be maintained in a clean and sanitary condition. All equipment and work surfaces shall be cleaned and decontaminated after contact with blood or other potentially infectious materials. Special training is required for housekeeping staff who are assigned to clean research laboratories where potentially infectious materials are handled.

An Integrated Pest Management Program (IPMP) is also important in research laboratories because some pests can transmit diseases and compromise the integrity of the work. While pest control is a facility-wide issue, research laboratory workers can contribute by keeping work and break areas clean and limiting the storage of cardboard and other paper products in the research laboratory.

7.14. Principles of Disinfection and Methods of Decontamination

There are various levels of reducing microbial load, ranging from clean to sterile. The process of rendering an area, device, item, or material safe to handle and minimize potential disease transmission is called decontamination, as stated in Appendix B of the BMBL, 5th edition. Decontamination can involve disinfection of work surfaces in which microbial load is reduced, or sterilization in which all microorganisms, including highly resistant forms, are eliminated. Research laboratories should develop a decontamination plan based on the type of research activities that are performed.

Some disinfectants kill vegetative microorganisms and deactivate viruses but are not effective against bacterial spores. These disinfectants may be capable of sterilization only when the contact time is relatively long (e.g., 6 to 10 hours). Mid-level disinfectants kill vegetative microorganisms, including *Mycobacterium tuberculosis*, all fungi, and most viruses. The EPA approves and registers antimicrobial products commonly used as disinfectants in research laboratories for disinfection of benches and housekeeping purposes. Information on EPA-approved antimicrobial products is available online at: http://www.epa.gov/oppad001/chemregindex.htm.

The effectiveness of a disinfection procedure is influenced by a number of factors, including the agent (Table 7-1), biological load, contact time, temperature, etc. These factors and the intended use should be considered in the selection of a disinfectant (Table 7-2).

Table 7-1: Examples of Microorganisms and Disinfectant Effectiveness

	Chlorine Compounds	Alcohol	Phenolics	Quaternary Ammonium Compounds (Quats)
Bacteria	Very good	Good	Good	Good for gram positive
Envelope Viruses	Very good	Good	Good	Good
Non-Envelope Viruses	Very good	Fair**	Fair**	Not effective
Fungi	Good	Fair	Good	Fair
Bacterial Spores	Good with high concentration	Not effective	Not effective	Not effective
Protozoa Parasites*	Moderate with high concentration and long contact time (hours)	Not effective	Not effective	Fair (some quats at high concentration)

*Hydrogen peroxide most effective.
**Check disinfectant efficacy for individual viruses.

Table 7-2: Major Groups of Disinfectants: Advantages and Disadvantages

Type	Advantages	Disadvantages	Notes
Chlorine Compounds	Low cost. Fast acting. Broad spectrum effectiveness.	Corrosive. Irritant. Produces toxic gas if mixed with acids or ammonia compounds. Can be less effective in the presence of large amounts of organic materials.	Must be made fresh daily. 1:10 ratio of bleach to water. Use to decontaminate liquid culture media, for spill clean-up, and to wipe down work surfaces.
Alcohols	Non-corrosive.	Flammable. Not effective against spores. Limited effective exposure time due to high rate of evaporation.	Solutions less than 50% volume for volume in water are ineffective as a disinfectant. Disinfectant of choice when working with HBV and HIV.
Phenolics	Effective in organic material. Has some residual effectiveness.	Not effective against spores. Corrosive. Toxicity varies with the specific phenolic compound. Can be absorbed through the skin.	Useful in areas, such as cabinet ridges, where organic material cannot always be removed.
Quaternary Ammonium Compounds (Quats)	Strong surface activity. Non-corrosive. Low-toxicity.	Easily inactivated by organic materials, anionic detergents, and the metal salts found in hard water.	Commonly used to clean walls, floors, etc. Surface must first be rinsed free of anionic soap or detergents.

Chemicals that are potent sporicides are classified by the Food and Drug Administration (FDA) as sterilant/disinfectants. They are formulated for use on medical devices but not on environmental surfaces, such as research laboratory benches or floors. The FDA regulates high-level disinfectants and sterilants. A list of products is available online at: http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/ReprocessingofSingle-UseDevices/ucm133514.htm. Additional information and principles for disinfection and sterilization are provided in the CDC publication "Guideline for Disinfection and Sterilization in Healthcare Facilities" (2008).

7.14.1. Factors Affecting Decontamination

There are certain factors that can influence the decontamination of surfaces and equipment, including, but not limited to:

- Sufficient contact time, as specified on the disinfectant label.
- Removal of organic material prior to disinfecting.
- Surface type (porous, uneven surfaces, hard surface, etc.):
    - Porous surfaces are more difficult to decontaminate and in some cases may not be successfully decontaminated.
    - Hard surfaces are easier to decontaminate.
    - Total decontamination of uneven surfaces may be difficult due to unequal distribution of the disinfectant.
    - Disinfectant must reach all surfaces of equipment with ridges and/or small apertures.
- Temperature, which can affect contact time for thorough decontamination and/or the effectiveness of the disinfectant.

Furnishings in research laboratories should be constructed of impervious material and surfaces that can be disinfected. Carpet and cloth chairs should not be used in research laboratories.

7.14.2. Spill Clean-Up

Spills involving infectious materials must be contained, cleaned, and decontaminated by appropriate professional staff or others properly trained and equipped to work with infectious material. A spill procedure must be developed and available within the research laboratory. A sample biological spill response procedure can be found in Enclosure 7-1. Additional information can be found in the Mount Sinai School of Medicine "General Guide For Biological Spill Responses."

7.15. BSCs

BSCs are the primary containment devices used when working with infectious materials. There are three types of BSCs designed for working with low to moderate risk biological agents (Class I and II) and high risk biological agents (Class III). Class II BSCs are most commonly used in VHA research laboratories and provide protection for research laboratory workers, work surfaces, and the environment from exposure to biohazards and/or cross contamination during routine procedures.

Research laboratory workers should use BSCs when procedures involving infectious materials are likely to create aerosols. All experiments involving highly-infectious or airborne-transmitted pathogens must be conducted inside BSC units. Good research laboratory techniques and preventive maintenance are essential to ensure effective containment within the BSC.

A risk assessment should be conducted by the Research Chemical Hygiene Officer (RCHO) or facility Safety Office prior to working with chemicals in BSCs. Additional information on primary containment in research laboratories can be found in Appendix A, Primary Containment for Biohazards, of the BMBL, 5th edition (http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf#page=312).

7.15.1. Class I BSC

Class I BSCs are used to protect the product, but not the user or environment, from contamination and have limited uses in VHA research laboratories. The BMBL, 5th edition provides detailed information on Class I BSCs.

7.15.2. Class II BSC

Class II BSCs have three key features:

- Front access with inward air flow to protect the user.
- HEPA-filtered air blowing down from inside the cabinet to protect the work surface and materials.
- HEPA-filtered air exhausted to the room.

Air exhausted to the outside must be HEPA-filtered for Class IIB BSCs, but it is recommended for all Class II BSCs.

It is important for the front grills and back vents to remain free of obstructions (e.g., arms, papers, equipment) to allow the required air circulation within the cabinet. Figure 7-6 is an illustration of airflow in a Class II BSC.

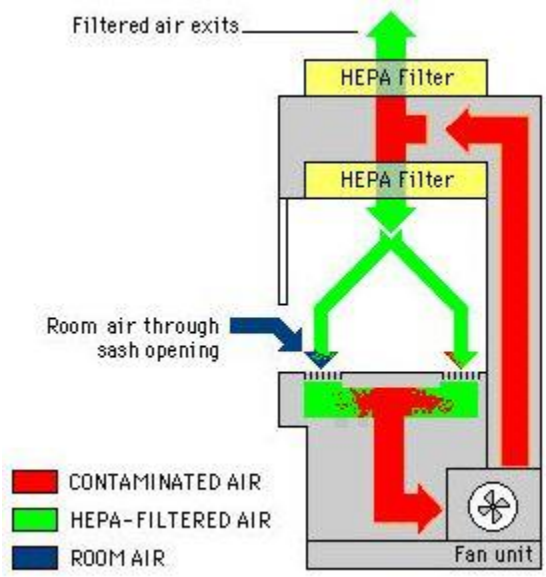

Figure 7-6: Airflow in Class II BSC (Source: U.S. Department of Agriculture)

7.15.3. Class III BSC

Class III BSCs is designed for work with highly infectious microbiological agents and highly toxic compounds. These cabinets provide maximum protection for the

environment and the worker and have limited uses in VHA research laboratories. Four key features associated with Class III BSCs include:

- Totally enclosed gas-tight construction fitted with glove and material interchange ports.
- Operation under negative pressure.
- HEPA-filtered supply and exhaust air.
- Cabinet exhaust air is filtered through two HEPA filters in series to the outside of the building.

7.15.4. Work Practices for Proper Use of BSCs

Effective containment depends on a well-maintained BSC and good microbiological technique. Certain work practices, if performed before and while working in BSCs, can help ensure the safe handling of biological materials.

Prior to working in a BSC:

- Plan experiments in advance and gather all necessary materials.
- Verify that BSC certification is current.
- Wear appropriate PPE, such as laboratory coat, gloves, and eye protection.
- If an ultraviolet (UV) lamp unit is being used, turn it off as soon as you enter the room.
- Turn on all blowers and cabinet lighting at least 3-5 minutes prior to starting work.
- Verify that safety features (e.g., sash, alarm, filter pressure gauge) are operational.
- If present, drain valves should be closed.
- Decontaminate all interior surfaces of the BSC with an appropriate disinfectant (e.g., 70% ethanol or 1:10 dilution of bleach).
- All containers and materials (supplies, equipment, etc.) placed inside the BSC should also be wiped with an appropriate disinfectant.
- Place the minimal amount of materials necessary to complete the experiment inside the BSC.

When working in a BSC:

- Minimize all movement into, out of, and near the BSC.
- Arm movements in and/or out of the BSC should be slow and perpendicular to the face opening.
- Do not block the front grill or back vents with papers or materials.
- Work at least 4 inches from the inside edge of the front vent.
- Minimize spills and splatters when working with infectious materials and keep all waste and contaminated articles inside the BSC until disposal.
- Use horizontal pipette containers. Upright pipette collection containers should not be used in the BSC or placed on the floor outside the BSC.

- Maintain sash at appropriate height.
- Disposable pre-sterilized equipment, flameless, or on-demand sterilization methods should be used as much as possible.
- Work should flow from clean supplies to contaminated areas (as shown in Figure 7-7) to prevent cross-contamination of experimental materials.

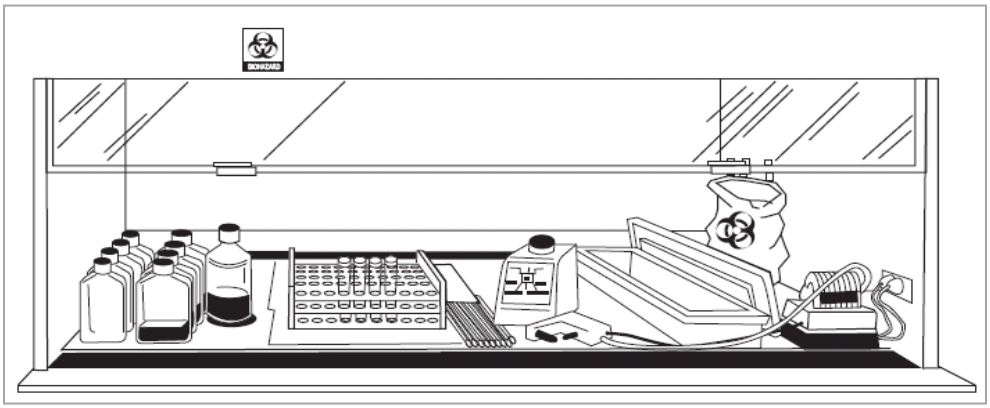

Figure 7-7: BSC Diagram with Items Arranged to Reduce Contamination
(Source: BMBL, 5th edition)

- Use of Bunsen burners is not permitted in BSCs. Electric furnaces should be placed in the back third of the BSC.
- Laboratory personnel must be aware of fire hazards associated with alcohol-based disinfectant vapors because Class II BSCs typically do not have spark-proof fans and electrical outlets.
- As illustrated in Figure 7-8, aspirators or vacuum lines should be connected to a labeled collection trap containing an appropriate disinfectant, an overflow flask, and an in-line HEPA filter to prevent particulate aerosols from contaminating the vacuum system.

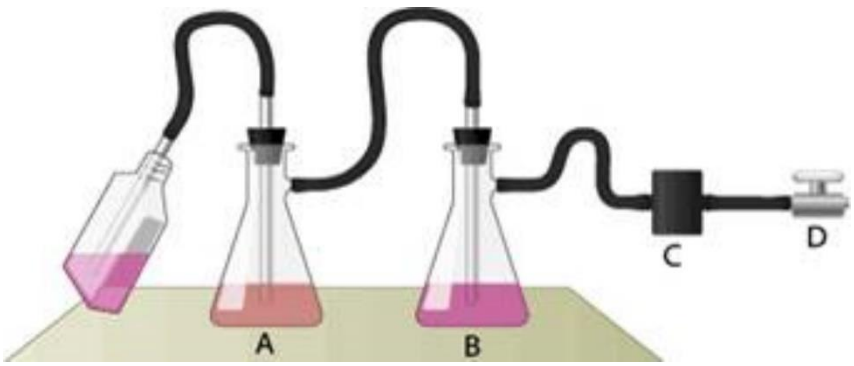

Figure 7-8: House Vacuum Diagram with a Waste Collection Flask (A), Overflow Flask (B), In-Line HEPA Filter (C), and Vacuum Source (D)
(Source: Columbia University)

- Surfaces should be disinfected immediately after working with infectious agents.

- For major spills, follow local procedures for reporting and decontamination.

When work in the BSC is completed:

- Collect waste materials inside the BSC. Be sure to seal bags and cover open containers.
- Decontaminate the exterior surface of all items prior to removing them from the BSC.
- After all decontaminated waste containers are removed, wipe the interior surfaces with an appropriate disinfectant.
- Allow BSC blowers to run for at least 5 minutes before shutting the unit down.
- Do not use the BSC to store equipment or supplies.

The BMBL, 5th edition, Appendix A, provides information on selection, installation, and use of BSCs.

7.15.5. UV Lamps

In general, the use of UV lamps in BSCs is not recommended because it is not effective on opaque porous surfaces. In addition, UV does not penetrate shadowed areas; material covered by dirt, dust, or organic matter; or inside grills or vents. However, if a UV lamp is used in a BSC, the following procedures should be followed:

- Post a warning sign to turn off the UV lamp before working.
- Train staff in potentially harmful UV effects such as burns, eye injuries, deterioration of equipment/materials (especially electrical cords), and potential for skin cancer with over-exposure.
- Periodically monitor the UV lamp intensity (e.g., semi-annually).

A detailed discussion of the use of UV lamps can be found in the Meechum and Wilson article "Use of Ultraviolet Lights in Biological Safety Cabinets: A Contrarian View."

7.15.6. BSC Certification

A BSC must be certified annually and after installation, repair, relocation, or replacement of the HEPA filter. BSCs used for airborne pathogens must be certified semi-annually. The VHA adopted NSF®/American National Standards Institute (ANSI) 49, Biosafety Cabinetry: Design, Construction, Performance, and Field Certification, as the certification criteria for BSCs.

Certifications should be conducted by qualified individuals. The NSF® International website provides links to NSF®-accredited certifiers.

A good practice is to maintain an inventory of all BSCs for scheduling preventive maintenance and re-certification. The results of the certification should be documented and signed by the certifier. A certification label should be applied with the certification date, inflow air velocity, filter pressure gauge reading, and name of the certifier. A record of the certification results should also be maintained according to the facility policy.

7.16. Biohazardous Material Transportation

Transportation of all hazardous substances is regulated by the U.S. Department of Transportation (DOT) and the International Air Transport Association (IATA).

DOT regulations apply to vehicular transportation of hazardous materials and personnel who package, transport, and receive these goods. The regulations primarily apply to commercial transportation but also include transportation in private vehicles or between institutions. Employees are required to be specifically trained for the task they perform *every 3 years*. An overview of these requirements can be found online at: http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm.

However, if transported by air, IATA requirements apply, and training is required *every 2 years*. Current information can be found on the IATA Infectious Substances website. All transported specimens must meet 29 CFR 1910.1030 labeling and packing requirements.

Basic considerations for safe transport include:

- Biohazardous material should be placed in a sealed and labeled primary specimen container.
- The sealed primary container should be placed into a dedicated secondary container with absorbent packing to cushion the primary container and to absorb liquids in the event of a leak or spill.
- The secondary container must be sealed and labeled with a biohazard symbol.

7.16.1. Non-Commercial Transportation

When being transported by hand, hazardous materials should be identified and securely packaged in primary and secondary containers. In addition, the transportation route should not be in public areas, and dedicated elevators should be used whenever possible. Individuals transporting hazardous materials should be aware of their environment at all times to avoid slips, trips, and falls.

Transportation of hazardous materials in official government or personal vehicles carries specific personal and institutional liability issues and should be discouraged. However, any transportation on a public road requires proper packaging, identification, and labeling (consistent with DOT regulations) as well as training of personnel involved.

7.17. References and Resources

1. 29 CFR 1910.1030, Bloodborne Pathogens.

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11. World Health Organization. (2000). WHO Infection Control Guidelines for Transmissible Spongiform Encephalopathies. WHO, Geneva, Switzerland: http://www.who.int/csr/resources/publications/bse/WHO_CDS_CSR_APH_2000_3/en/.

7.18. Enclosures

Fact Sheets for Research Laboratory Guidebook

The following fact sheets contain quick-reference information relevant to this chapter:

5.1 General Precautions
5.2 Control of Biological Hazards
5.3 Bloodborne Pathogens

Enclosure 7-1 Sample Biological Spill Response Procedures

Enclosure 7-2 Sample Form for Declaration of Equipment as Free of All Hazards

Physical Safety in Research Laboratories

8.1. Introduction

There are many physical hazards found in research laboratories that have the potential to cause injury to research laboratory workers. This chapter is intended to provide an overview and understanding of significant physical hazards including:

- Fire safety
- Slips, trips, and falls
- Housekeeping
- Noise
- Electrical
- Glassware
- Compressed gases
- Cryogenic agents
- Oxygen
- Research laboratory equipment

The physical hazards associated with the use of radiation are covered in Chapter 9, Radiation Safety in Research Laboratories.

8.2. Fire Safety, Access, and Egress

Fire is a significant concern in research laboratories because it can cause severe injuries to staff and result in the destruction of property. There is a high fire risk in research laboratories because flammable liquids are commonly used, flammable vapors can be generated, and flames and heating elements are common. Minimizing the storage and use of flammable chemicals reduces the risk of large fires. More information on flammable chemical handling and management can be found in Chapter 4, Management of Hazardous Chemicals in Research Laboratories, and Chapter 5, Chemical Safety in Research Laboratories.

8.2.1. Fire Safety Codes

The determination of applicable fire safety codes is based on building classification, types of flammable or combustible materials, quantities of hazardous materials present, and occupancy type. Fire safety code compliance is evaluated by the facility Safety Office with support from Veterans Integrated Service Network (VISN) Fire Protection Engineers or VISN Safety Managers. For more information, please consult the VHA Fire Safety Guidebook.

Requirements for emergency access and egress and fire protection planning are addressed in Code of Federal Regulations (CFR) 29 CFR 1910.36-1910.39.

The most recent version of the National Fire Protection Association (NFPA®) 101, Life Safety Code, is VHA policy and accepted by the Occupational Safety and Health Administration (OSHA). NFPA® 45, Standard on Fire Protection for Research Laboratories Using Chemicals, provides specific instruction on fire safety in the research laboratory. Both codes are available through the Healthcare Environment and Facilities Programs (HEFP) website.

Basic guidelines for fire safety include:

- Ensure that the research laboratory staff is aware of procedures to be followed during a fire.
- Ensure that emergency exit routes are clearly marked and free of obstructions.
- Encourage employees to identify issues that might impede emergency access and egress.
- Illuminate and identify evacuation routes with an exit sign.
- Establish an interim evacuation plan for research laboratories that are under renovation or construction.
- Keep fire doors closed.
- Properly store and limit the total volumes and flammable chemicals used in the research laboratory. Keep containers closed when not in use.
- Prohibit the disposal of flammable liquids or incompatible chemicals into drains.
- Inspect electrical equipment, especially power cords, for defects and other potential ignition sources prior to use.
- Limit the use of extension cords, power strips, or similar devices unless approved in advance by the facility Safety Officer.
- Report any deficiencies to the facility Safety Office or Engineering.

Fire drills are required at least once annually and should include simulation that test workers' knowledge. For example, during a fire drill, a person can be stationed at a stairwell entrance and inform evacuees that the stairwell is filled with smoke in order to test participants' familiarity with alternative exit routes.

In addition to flammable and combustible chemicals, objects such as wooden furniture, cardboard boxes, and paper all contribute to the fire load in research laboratories. Research laboratory equipment can serve as ignition sources if not properly operated, maintained, and attended. Controlling ignition sources in the research environment is critical; therefore, open flames should be minimized.

8.2.2. Fire Extinguishers

Employees expected to use fire extinguishers must be trained annually on the location of fire extinguishers, when and how to use fire extinguishers, and the limitations of extinguisher classes. The use of fire extinguishers in research laboratories should be limited to individuals who have had proper training. A standard fire extinguisher found in research laboratories is a dry powder extinguisher for Class A, B, and C fires. Class A fires involve ordinary combustible materials, such as cloth, wood, paper, rubber, and several types of plastics. Class B fires involve flammable and combustible liquids, such as gasoline, alcohols, diesel oil, oil-based paints, and flammable gases. Class C fires involve energized electrical equipment. Dry powder residue from Class ABC or BC extinguishers can contaminate research laboratory equipment or samples; therefore, a Class BC fire extinguisher that contains *carbon dioxide* (CO_2) is often preferred for fires in or near sensitive research laboratory equipment. However, CO_2 extinguishers should never be used in a very small room or in a confined space because they can deplete oxygen.

Two other types of fire extinguisher classes are D and K. Class D fire extinguishers may be needed in research laboratories that contain combustible metals (e.g., magnesium, sodium) and should be located near the area where the metal is used or stored. Class K fire extinguishers are used for kitchen fires involving oil and grease. Research laboratories that contain powerful magnets, such as in magnetic resonance imaging (MRI) equipment, require a non-metallic fire extinguisher.

Additional information from OSHA regarding portable fire extinguishers is available in the Evacuation Plans and Procedures eTool and in 29 CFR 1910.157, Portable Fire Extinguishers.

8.3. Slips, Trips, and Falls

Slip, trips, and falls are one of the top five causes of injuries in the research laboratory setting. Slips, trips, and falls are caused by a number of hazards, including poor housekeeping, poor floor and aisle maintenance, wet floors, uneven surfaces, improper storage of equipment and supplies, and employee behavior.

29 CFR 1910 Subpart D, Walking and Working Surfaces, is intended to reduce accidents including slips, trips, and falls by setting minimum requirements for floors, ladders, stairs, and housekeeping.

Highlights of these requirements include:

- Keeping all work areas clean and orderly.
- Maintaining floors in a clean and dry condition. Where wet floors are not avoidable (cage washing areas), drainage shall be maintained and/or false floors, platforms, mats, or other dry standing places shall be provided when practicable.

Personnel should avoid behaviors that frequently contribute to slips, trips, and falls, including:

- Wearing inappropriate footwear.
- Carrying excessive boxes or other materials that inhibit line of sight.
- Using unapproved step aids (chairs, boxes, stools, etc.).
- Leaving electrical or phone lines on the floor.
- Ignoring wet or slippery floors.
- Storing heavy objects on high shelves.
- Leaving drawers or cabinets open.

8.3.1. Controls

Prevention of slips, trips, and falls should include:

- Training employees to recognize and report slip, trip, and fall hazards.
- Attending to floor spills quickly by placing a wet floor sign and cleaning the spill.
- Using non-slip matting, wet floor drain mats, and slip-resistant footwear in wet locations.
- Avoiding the storage of items on the floor except in designated areas.

For more information, see the OSHA Slips, Trips, and Falls e-Tool.

8.4. Housekeeping

In addition to contributing to fire hazards and slips, trips, and falls, excessive clutter and poor housekeeping can also impede access to emergency equipment. The following are common safety violations that must be avoided:

- Blocked emergency eyewash and shower stations.
- Blocked electrical panels.
- Fire extinguishers blocked.
- Permanent storage of chemicals in fume hoods.
- Long term storage of items in unapproved areas.
- Failure to remove surplus equipment.
- Dirty surfaces that attract vermin or pests to the work area.

8.4.1. Controls

Minimize clutter by only ordering material in quantities that can be used within a 3-6 month period. Cluttered spaces and crowded shelves (Figure 8-1) play a significant role in workplace injuries. Principal Investigators should periodically remove excess materials and equipment, and all safety inspections should target clutter.

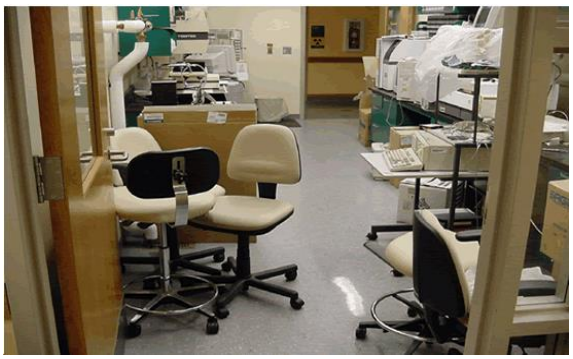

Figure 8-1: Cluttered Research Laboratory

8.5. Noise Hazards

Noise associated with the operation of chemical fume hoods, biological safety cabinets, and automated samplers are generally in the range of 60-75 decibels (dB), which is considered safe by OSHA as documented in 29 CFR 1910.95, Occupational Noise Exposure. However, other equipment emits noise at higher levels that can exceed the OSHA action level of 85 dB, including sonicators, blenders, grinders, homogenizers, compressors, and cage washing units. Therefore, anticipated noise levels should be considered when purchasing these types of equipment. Noise levels above the action level can also be associated with areas where large animals used in research (e.g., pigs, dogs, non-human primates) are housed. Additional information on noise levels can be found in OSHA Fact Sheet, Laboratory Safety Noise.

Noise levels in research laboratories are usually intermittent and do not typically approach levels near, or in excess of, permissible exposure limits (PELs). The noise standard and the Hearing Conservation Amendment define the PEL as the noise dose that would result from a continuous 8-hour exposure to a sound level of 90 dB. This is a dose of 100%. Duties where workers are known to be exposed to noise levels above the action level will require the use of hearing protection devices (HPDs), including ear plugs, ear muffs, or both when engineering or administrative controls do not effectively reduce the exposure. Noise exposure measurements are reported as time-weighted averages (TWAs), meaning louder noises have a shorter acceptable period of exposure (Table 8-1).

Table 8-1: OSHA Permissible Noise Exposures

Duration per Day in Hours	8.0	6.0	4.0	3.0	2.0	1.5	1.0	0.5	0.25
Sound Level, Decibels	90	92	95	97	100	102	105	110	115

When noise exposures exceed 85 dB or above, a written Hearing Conservation Program (HCP) must be implemented that includes:

- Medical monitoring, including baseline and annual audiograms.

- A detailed evaluation of exposure(s).
- Proper selection of HPDs, such as ear plugs or ear muffs.
- Requirement to use f HPDs when noise exposures exceed 90 dB. Best practice is to wear HPDs at 85 dB or above.
- Training to educate workers on hearing conservation techniques (e.g., proper use, care, and cleaning of hearing protection devices).
- Engineering controls, such as equipment enclosures, noise damping materials, and isolation devices to reduce exposures.
- Signage that identifies hazardous noise areas and processes.

8.5.1. Controls

Controls for noise hazards include:

- Engineering controls, such as laboratory design or structures or barriers to contain or isolate noise (e.g., noise baffles, insulation in ductwork).
- Administrative controls, including training, eliminating or minimizing worker exposure time, and identifying safe work distances.
- HPDs.

8.6. Electrical Hazards

The major hazards associated with electricity are electrical shock and fire. Shock occurs when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a part of a piece of equipment that has become energized. Additional information and VHA electrical safety requirements can be found in the VHA General Safety Guidebook.

Electrical hazards can be reduced by taking reasonable precautions such as:

- Equipment should be double insulated with a 2-prong plug, have a grounded 3-prong plug, or be used in a 3-prong outlet. An adapter plug (Figure 8-2) should never be used, and the 3rd prong (grounding post) should never be removed.

Figure 8-2: 3-Prong Plug Adaptor for 2-Prong Outlet

- Any outlet within 6 feet of a sink, in wet areas, or in any area where electricity and water may come in contact must have ground fault circuit interrupter (GFCI) protection (Figure 8-3). The GFCI should be periodically tested by verifying that equipment will shut off when the test button is pressed.

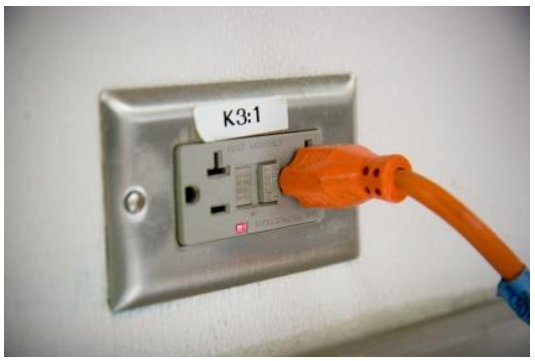

Figure 8-3: 3-Prong Outlet with GFCI

- Maintain electrical equipment and instrumentation in good working order, so that insulation is not frayed or wiring exposed.
- Never unplug equipment by pulling or yanking the cord.
- If liquids are spilled on equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
- Never connect multiple power strips together (e.g., daisy-chaining; Figure 8-4).

Figure 8-4: Power Strips Daisy-Chained Together

- Pay close attention to wiring/cords in areas where ultraviolet (UV) light is used for disinfection (such as biological safety cabinets) because UV light can cause rapid deterioration of electrical insulation.
- Never run power cords through doors, ceilings, walls, windows, damp areas, etc.
- Keep electrical panel doors closed and readily accessible.

8.6.1. Controls

Electrical hazards controls include:

- Inspect electric cords on equipment before use. Damaged cords and equipment must not be used and must be reported immediately to the facility Safety Office and Engineering.
- Never use extension cords for routine work in the research laboratory.
- Do not overload power strips by using high-amperage equipment (refrigerator, microwave oven, hot plate, coffee pot, space heater), and exceeding the maximum rating of 15 to 25 amps.
- Keep flexible power cords off the floor.

8.7. Glassware Hazards

8.7.1. Description

Broken glass is the major hazard associated with research laboratory glassware. Glass bottles or other research laboratory equipment can break when dropped or can explode when strained from experimental conditions, such as heating. Cuts from broken glass can range from relatively minor contusions to severe impacts from flying shards. Injuries from broken glassware can be avoided through adherence to safety protocols, careful inspection and manipulation of glassware, and diligent use of protective equipment.

Surface scratches and chips are common defects that cause weakness and breakage in the glass; therefore, it is important to check each piece prior to use. A less visible hazard is glass stress, which can result when glass is heated unevenly above its strain point. Star cracks, glass stress, and other small defects can be repaired by annealing, but this process must only be performed by a qualified glass repair person. Repair of damaged glassware is generally not recommended.

Inserting a glass stem into a rubber stopper is another common research laboratory practice that can be dangerous without proper precautions because glass tubing can often break when pressure is applied during the insertion process. Understanding the properties of glass tubing and connecting materials can reduce the incidence of accidents and improve research laboratory safety. For more information on the safe handling of glass tubing, see Enclosure 8-1, Sample SOP: Glass Tubing, provides steps to safely work with glass tubing.

Borosilicate glass is commonly recommended for most research laboratory applications except for special experiments that use UV or other light sources. This glassware combines strength and clarity with chemical and heat resistance. Research laboratory borosilicate glassware can commonly be found under brand names such as Pyrex® (Corning 7740) and Duran® (Schott 8830). While borosilicate glass items will break if dropped, some glassware can be purchased

with plastic coating to eliminate the sharp edges of broken glass and contain liquid contents. Reagent bottles, measuring equipment, stirring rods, and tubing are not usually made of borosilicate glass.

8.7.2. Controls

General precautions for preventing glassware hazards include:

- Using appropriate glassware according to written research laboratory procedures.
- Avoiding the use of glass when a stronger material or apparatus can suffice.
- Handling glassware carefully to minimize damage and protect the integrity of the glassware.
- Avoiding impacts, scratches, and intense heating of glassware.
- Inspecting glassware for cracks and defects before using.
- Properly disposing of glassware that is chipped, cracked, or otherwise damaged or worn.
- Providing cut-resistant gloves to personnel performing operations where glassware is likely to be broken.
- Wearing heavy, synthetic, water-resistant gloves when washing glassware by hand.
- Using a broom and pan to clean up broken glass instead of handling broken shards.

Broken glass should be disposed of properly in a labeled cardboard box or other rigid container that will protect housekeepers and other personnel from sharps exposures. Contaminated broken glass may require disposal as a hazardous waste in a properly-labeled container. Broken glass containment boxes are pictured in Figure 8-5. Broken glassware contaminated with biological or chemical hazards must be disposed of in compliance with hazardous/infectious waste regulations.

Figure 8-5: Broken Glass Containment Boxes
(Source: Krackeler Scientific, 2011)

Glassware under either positive or negative pressure is at risk for explosion or implosion. Pressurized glass vessels are also susceptible to cracking or rupture from mechanical blows or rising temperature. Examples of pressurized glassware include Dewar flasks, desiccators, thick-walled Erlenmeyer flasks, and round-bottom flasks.

Positive or negative pressurized glassware hazards controls include:

- Discontinue use of glassware beyond the recommended safety limit and do not subject it to sudden pressure changes. Round vessels will generally tolerate more pressure or vacuum than flat-sided vessels of similar construction.
- Use a safety screen or impact-resistant shielding and personal protection when using mechanically pressurized or vacuum pump systems. A chemical fume hood sash can also be used as a safety screen.
- Reinforce glassware for vessels that may implode, such as Dewars or desiccators, with friction tape applied in a single layer in a pattern that guards against flying glass.
- Place a warning sign on apparatus under pressure.

Heating glass at high temperatures may create permanent stresses in the glass because continued heating or localized hot spots can cause the glassware to break. Repaired glassware often has weak spots that may rupture under changes in temperature or pressure. Since hot glass looks like cool glass, precautions must be taken while working with heated glassware.

Heated glassware hazards controls include:

- Using tongs or heat-resistant gloves to remove glassware from sources of heat.
- Using a soft flame with a Bunsen burner, as well as a wire gauze or diffuser to prevent localized heating.
- Heating the whole lower hemisphere of a flask to prevent localized hot spots.
- Avoiding the use and heating of volumetric cylinders and flasks on hot plates.
- Establishing procedures to cool hot glass items prior to removal from heated equipment, such as autoclaves or ovens.

8.8. Compressed Gases

A wide variety of compressed gases are used in the research laboratory setting. Some uses of compressed gases include fuel gases for instruments, inert gases as carrier gases within instruments, oxygen and nitrous oxide in animal surgeries, CO_2 for euthanasia of small rodents or to create a slightly acidic and oxygen-deficient atmosphere in incubators, and ethylene oxide for sterilization. *Note: Chemical hazards are covered in Chapter 5, Chemical Safety in Research Laboratories.*

8.8.1. Description

Compressed gases are stored in cylinders manufactured according to the U.S. Department of Transportation (DOT) regulations, which specify the material of construction, method of manufacture, testing, and compatible product fill. Compressed gas cylinders come in different sizes and are typically composed of a single piece of steel with a shape ideally suited to withstand internal pressures to which the cylinders are routinely subjected. Compressed gas cylinders have a pressure-relief device installed to prevent rupture if a normally pressurized cylinder is inadvertently exposed to fire or high temperatures.

The valve stem is the most vulnerable part of a compressed gas cylinder and should be protected with a valve cap or cover that remains securely in place at all times when the cylinder is being stored or moved. Without a valve cap, a dropped cylinder may dislodge or damage the valve, and the pressurized cylinder could become a missile that is capable of penetrating walls, concrete blocks, and other structures, as well as expelling the gaseous contents along the way. Likewise, movement of compressed gas cylinders should be performed only after securing the cylinder to an appropriately-sized four-wheel compressed gas cylinder cart (Figure 8-6).

Figure 8-6: Four-Wheel Compressed Gas Cylinder Carts
(Sources: Left: Airgas, 2011; Right: Princeton University, 2011)

When receiving gases, it is important to perform a basic inspection of each cylinder. This inspection should include at least the following:

- Confirm that the cylinder appears to be in good condition with no significant physical defects (e.g., dents) and no significant rust (a minor scratch with rust is acceptable).
- Ensure that the cylinder cap is securely in place but can be removed by hand.
- Check that the cylinder has an intact label that identifies its contents and DOT hazard classification.
- Ensure that the cylinder is secured in the upright position, as illustrated in Figure 8-7, at all times.

Figure 8-7: Proper Cylinder Restraint
(In a seismic area, two chains are required.)
(Source: University of California, San Diego, 2011)

8.8.2. Equipment Regulators

Pressure regulators (Figure 8-8) reduce the high pressures of gas stored in the cylinder to lower pressures that can be used safely in an operating system. Proper regulator selection is critical for both safety and effectiveness of operating systems. Selection is based on the type of cylinder, specific gas, and pressure.

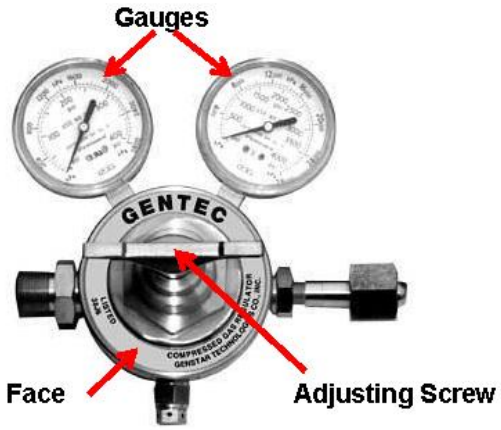

Figure 8-8: Regulator

Regulators can explode. Always stand to the side of the regulator face, preferably with the valve between your body and the regulator. Avoid reaching in front of the regulator face to open the valve. The face of the regulator should always be angled upward (provided a flow meter is not attached), so that if there is an explosion, the adjusting screw and debris will fly away from your face. Regulator connections to cylinder valves must be completely free of dirt, dust, oil, and grease. ***Warning: Petroleum grease on an oxygen cylinder fitting can cause an explosion!***

Before attaching the regulator, open the cylinder valve slowly to release a small amount of the contents, which will clear dust and debris from the valve opening. *Note: Skip this step for cylinders containing toxic or corrosive gases.*

Regulators are attached to the cylinder or manifold at the inlet connection. This connection should be tested for leaks with a non-petroleum based product. The connection is marked with a Compressed Gas Association (CGA) number and will be left-hand or right-hand threaded to match the nut or fitting to prevent a regulator from being connected to the wrong gas supply. Right-handed CGA fittings will have a smooth nut surface and have an even number for the second digit. Left-handed CGA fittings will have a notched groove in the surface and have an odd number for the second digit.

Never use damaged or defective equipment.

8.8.2.a. Tips for Using Regulators

Eye protection must be worn and a face shield is recommended when opening a regulator. Stand on the *valve* side of the cylinder at arm's length to avoid reaching in front of the regulator face. Turn away from the regulator and open the valve, turning counter-clockwise, to blow out dust and debris, and then reclose the valve (Figure 8-9).

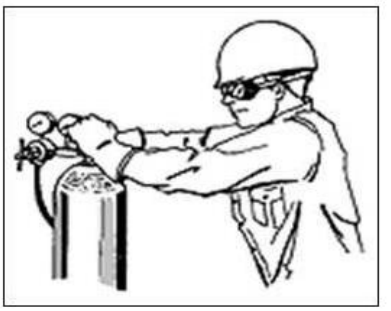

Figure 8-9: Proper Position for Opening a Regulator
(Source: Virginia Tech Environmental Health and Safety, 2011)

When changing a regulator, close the valve and drain the regulator by backing out the adjusting screw. When closing a regulator, turn the valve clockwise. Drain the regulator by opening the adjusting screw to release any gas and then reclose the adjusting screw.

8.8.2.b. Tips for Using Valves

The following are best practices for using valves:

- Do not attempt to open a corroded valve because it may not reseal completely.
- Ensure that cylinders without fixed hand wheels have keys, handles, or non-adjustable wrenches on the valve stem while they are in service.
- Do not open acetylene valves more than one and a half turns.
- Close valves before moving a cylinder, when work is completed, and when the cylinder is empty.

8.8.3. Physical Hazards of Compressed Gases

Some physical hazards associated with compressed gases include:

- Pressure: Compressed gas cylinders are designed to hold gases with varying pressures. The cylinder and valve assembly should be matched to the specific gas contents and have pressure-release devices that must remain unobstructed. If a cylinder is bulging or otherwise deformed, it should be taken out of service. Cylinders with valve-protection caps must have the caps in place when the cylinder is in storage or in transport. If a cylinder falls and the valve is damaged, the cylinder can become a

projectile and cause significant damage in the immediate area if the gas is released.

- Simple asphyxiants: Some compressed gases can cause suffocation by displacing oxygen in the air. Examples of asphyxiants used in the research laboratory include CO_2 and nitrogen. Detailed information is provided in Enclosure 5-1, Additional Toxicology Information.

- Flammability: Flammable gases should be stored and secured in places where there is good ventilation, no ignition sources, and appropriate mechanisms for fire detection and suppression. Examples of flammable gases used in the research laboratory are propane (heavier than air) and hydrogen (lighter than air). Flammable gases that are heavier than air may pool or concentrate in low spots, such as along the floor. Similarly, flammable gases that are lighter than air can pool along the ceiling or under ceiling tiles. Remember that each flammable gas has its own unique level of risk based on its flammable range. All flammable gas connections and tubing should be periodically inspected for potential leaks.

- Corrosion: The acid gases classified as corrosives by DOT degrade metal and damage human tissue. Examples of corrosive gases used in the research laboratory are hydrogen chloride and ammonia. Corrosive gases should always be handled using an appropriate corrosive-resistant apparatus in a chemical fume hood.

- Pyrophoric gases: Pyrophoric gases are compressed gases that have an auto-ignition temperature below 54.4 degrees Celsius (°C) [130 degrees Fahrenheit (°F)] that are rarely used in research laboratories. Examples of pyrophoric gases used in the research laboratory include saline and diborane.

8.8.4. Compressed Gas Storage

Cylinders must be stored properly as follows:

- Cylinders must be stored in compatible groups (flammables should be separate from oxidizers and corrosives; highly toxic gases may require a ventilated gas cabinet).

- Full cylinders must be separated from empty cylinders.

- Empty cylinders must be clearly marked and stored carefully because residual gas may remain in the cylinder.

- Never rely on the color of the cylinder for identification because color-coding is not standardized and may vary between the manufacturer and supplier.

- Return old, unclaimed, or unused compressed gas cylinders to the compressed gas supplier at least annually.

An *interior* compressed gas storage room is a separately ventilated, fully enclosed room in which only compressed gas equipment and supplies are stored and/or used. Other requirements for interior storage include:

- The walls, floors, and ceiling must be constructed of non-combustible materials and have a fire-resistant rating of not less than 1 hour. In some cases where flammable gases are being dispensed, a 2-hour rating or greater may be necessary, as well as pressure-relief explosion blow out venting panels.
- The entrance to the room should be labeled in accordance with NFPA® 704, Standard System for the Identification of the Hazards of Materials for Emergency Response.
- The lighting, heating, and electrical appliances should be rated for hazardous atmosphere per NFPA® 45.
- Gas storage areas shall be kept free of all combustible materials (i.e., cardboard boxes).

A gas detection system should be installed in a room where toxic, flammable, or asphyxiant gases are being dispensed or used.

Exterior compressed gas storage rooms must be located in a secure area, protected from weather conditions, and ventilated. Other requirements for exterior storage include:

- Securing stored cylinders in place in an upright position.
- Locking the storage area and limiting access to authorized personnel only.
- Ensuring that the area is free of debris accumulation (e.g., leaves and other combustible materials).
- Posting a “No Smoking” sign in the area.
- Labeling the entrance to the room in accordance with NFPA® 704.

8.8.5. Controls

The following are some of the general actions that can be taken to ensure an acceptable level of safety associated with the use of compressed gases:

- Compressed gases shall be handled only by properly trained persons. Individuals without previous compressed gas experience will be provided on-the-job training and be supervised by an experienced employee.

- Training must be documented and include both safe compressed gas handling and the specifics of the health hazards and dangerous physical properties.
- Cylinders should never be dragged, rolled, or lifted by their valve caps.
- Employees moving gas cylinders should wear appropriate footwear and work gloves.
- Compressed gas shall not be delivered, picked up, stored, or put into service in exits, stairwells, or egress routes.
- A bench clamp (Figure 8-10), a cylinder base stand (Figure 3-11), or chains are possible ways compressed gas cylinders can be secured when in use. Bench clamps may not attach properly to smooth work benches and may be dislodged in a high traffic area.

Figure 8-10: Bench Clamp (Source: OpticsPlanet, 2011)

Figure 8-11: Cylinder Base Stands (Source: Magmedix, 2011)

- Cylinders that require a wrench to open the main valve should have the wrench left in place on the cylinder valve while open. Never apply excessive force when trying to open valves. Cylinders with stuck valves should be returned to suppliers for service.
- Do not attempt to open a corroded valve. Return the cylinder to the manufacturer for repair.

- Wear protective eyewear when changing out cylinders.
- Do not stand facing the regulator or valve when removing or attaching a regulator.
- Cylinder valves should be turned off and regulators drained when the gas is not in use.
- Follow local policies and standard operating procedures (SOPs) when using regulators (see Enclosure 8-2, Sample SOP: Operating Compressed Gas Systems).

The following guidelines for labeling and identifying the status of cylinders should be adhered to:

- Cylinder contents should be identified by the supplier's crescent-shaped adhesive identification label.
- Fixed research laboratory lines (plumbed) in gas manifold systems should be labeled to identify the contents.
- Affix a status label (full, in service, or empty) to each cylinder when received so that its progressive status can be tracked.

8.9. Cryogenic Agents: Liquefied Compressed Gas

Cryogenic liquids are primarily used in the preservation of biological material and in cold traps (often under vacuum). Hazards associated with cryogenic liquids include the transfer of cryogenic liquid, removal of materials from cryogenic containers, pressurization of cryogenic containers, and displacement of atmospheric oxygen. (See Section 8.10, Oxygen, for detailed information on oxygen-deficient atmospheres.)

8.9.1. Description

A cryogenic liquid is defined as a liquid with a normal boiling point (at normal, ambient pressure) below -150°C (-240°F). The most common cryogenic liquids include argon, helium, hydrogen, nitrogen, and oxygen. All of these substances are odorless, tasteless, and generally colorless.

The hazards of cryogenic agents can be considered from two perspectives. First, the hazards associated with the substance being in a cryogenic state (e.g., frostbite/burn hazard, oxygen displacement) and second, the hazards associated with the substance itself (e.g., flammable, reactive, and toxic). Cryogenic agents share the following hazards:

- Cryogenic liquids and their gases can rapidly freeze common materials such as steel, rubber, and plastics to the point that they become brittle or break under stress.

- Direct contact with cryogenic liquids can cause burns, frostbite, and more significant cellular damage resulting in irreversible tissue damage. The eyes are more sensitive to damage from cryogens or evolving cold gas than are the hands or face. Direct contact often results from the use of improper transfer equipment or techniques, as well as leaks or spills.
- Cryogenic liquids undergo a volume expansion when converting from the liquid to gas phase. This can create two significant hazards, physical stress on the container and displacement of oxygen in poorly-ventilated or enclosed areas.
- Screw-top cryovials can explode upon removal from storage if the liquid has penetrated the seal and becomes trapped in the vial. A quick, partial turn of the screw top will often release the expanding gas without compromising the contents.

Cryogenic liquids must be stored in vessels (such as Dewars) that can contain the cryogenic liquid under some amount of pressure. Portable tanks (Figure 8-12) used for storage and bulk cryogenic liquids are commonly seen in the research laboratory setting.

Figure 8-12: Portable Storage Tanks (Source: Cryo-News, 2009)

Like the fixed bulk storage tanks, portable tanks have sophisticated systems for pressure relief and dispensing bulk liquid cryogens. These cylinders may be affixed to larger equipment, such as imaging equipment, gradual freezing units, or used to fill Dewars or freezers directly. The pressure relief mechanism for all cryogenic containers should be inspected on a routine basis to ensure that icing (frozen water vapor from the air or frozen air) is not interfering with the proper function.

Dewars (Figure 8-13) are non-pressurized containers similar to a thermos (a bottle in a bottle) used for transferring smaller amounts of bulk liquid from a tank to a freezer or to a piece of equipment. Dewars themselves may also be used for temporary storage of a sample at cryogenic temperatures. Dewar openings are most often protected by a dust cap to allow expanding gas to escape and to

prevent ice from forming inside the neck, which can also create the potential for pressure build-up. For transfer purposes, Dewars can have a dispensing device, dippers, or a pressurized dispensing device.

Figure 8-13: Dewar Vessels (Source: Medical Supermarket, 2011)

Cryogenic freezers are storage vessels designed for the long-term storage of samples under cryogenic conditions. They are typically constructed from more robust materials, have additional insulation properties, and are often designed to receive specific types of carriers, holders, or other rack systems in which samples may be placed and immersed down into the cryogen. With samples in place, cryogenic freezers are often filled to 80% volume with cryogenic liquid. Some units are gas-tight with pressure relief devices similar to bulk storage units, while others allow gas to passively leak out. Examples of freezer/storage units and a suspended rack storage system are pictured in Figure 8-14.

Figure 8-14: Freezer/Storage Units and Suspended Rack Storage System
(Source: Vindon Scientific Limited, 2011)

Appropriate personal protective equipment (PPE), such as chemical splash goggles, face shield, apron, and gloves of insulated material should be used when handling cryogens. Wearing a research laboratory coat or long sleeves and cuff-less trousers/slacks is also recommended. Figure 8-15 shows examples of protective gloves and an apron that could be used when working with cryogenic materials.

Figure 8-15: Cryoprotective Gloves and Apron
(Sources: Left: Cardinal Health, 2011; Right: Tempshield Cryo-Protection, 2008)

NFPA® 55, Compressed Gases and Cryogenic Fluids Code, provides additional guidance on cryogenic systems and management. NFPA® 55 can be accessed through the HEFP website.

8.9.2. Controls

Controls for cryogenic liquid hazards include:

- Training employees on the hazards, proper PPE, and safe work practices prior to working with cryogens. Training must be documented. An SOP for the safe handling of liquid nitrogen, a representative cryogen, is provided in Enclosure 8-3.
- Ensuring that transfer systems, containers, and storage devices are approved for cryogens in use.
- Installing, maintaining, inspecting, and using cryogenic systems according to manufacturer instructions by qualified personnel.
- Providing fixed and/or portable oxygen monitors in locations where cryogen use may result in oxygen-deficient atmospheres.
- Dispensing and storing cryogenic liquids in well-ventilated areas.
- Using appropriate filling funnels, transfer devices, and/or transfer tools for pouring or transfers of cryogenic liquids.

- Ensuring that appropriate PPE is available and used by personnel when handling cryogenic agents.

8.10. Oxygen

8.10.1. Oxygen-Deficient Atmosphere

OSHA defines oxygen-deficient atmospheres as those with less than 19.5% oxygen. The OSHA limit is widely accepted because of the significant health effects (including death) that can occur, as well as the fact that depleted oxygen concentrations affect the ability of a person to self-rescue or otherwise rationally assess their situation. Health effects due to exposure to oxygen-deficient atmospheres are provided in Table 8-2.

Table 8-2: Health Effects Due to Exposure to Oxygen-Deficient Atmospheres

Percent Oxygen Concentration	Health Effects
19%	Some adverse physiological effects occur, but they may not be noticeable.
15-19%	Impaired thinking and attention. Increased pulse and breathing rate. Reduced coordination. Decreased ability to work strenuously. Reduced physical and intellectual performance without awareness.
12-15%	Poor judgment and coordination. Abnormal fatigue upon exertion. Emotional upset.
10-12%	Very poor judgment and coordination. Impaired respiration that may cause permanent heart damage. Possibility of fainting within a few minutes without warning. Nausea and vomiting.
<10%	Inability to move. Fainting almost immediately. Loss of consciousness. Convulsions. Death.

Virtually any gas can act as a simple asphyxiant and dilute the concentration of atmospheric oxygen. In the indoor atmosphere of the research laboratory, this mixing of gases may not be immediate or uniform. Issues of density, temperature, and source may cause the offending gas or gases to settle, mix, or rise. In the research laboratory, oxygen-deficient atmospheres occur when there is a leak of an oxygen-displacing gas in poorly-ventilated areas. For detailed information about asphyxiants, see Enclosure 5-1, Additional Toxicology Information.

An oxygen-deficiency hazard calculator that can be used for compressed gases is available online at: http://www.bnl.gov/esh/shsd/SEG/SMEToolsExt/ODHCompressGasR3.aspx. Additionally, an oxygen-deficiency hazard calculator that can be used for gases that liquefy when compressed (cryogens) is available online at: http://www.bnl.gov/esh/shsd/SEG/SMEToolsExt/ODHCryogenR4.aspx.

8.10.1.a. Dry Ice

Solid CO_2, referred to as dry ice, should be stored and used in a well-ventilated area because it evaporates by sublimation (phase change from a solid to a gas without passing through the liquid state). Dry ice can cause frostbite, thermal burns, and possible asphyxiation. ***Warning: Dry ice must NOT be stored in cold rooms or walk-in freezers because it can create an immediately dangerous to life and health (IDLH) atmosphere.*** Warning signs should be posted accordingly to prevent accidental use during emergency situations.

Other hazards of dry ice include:

- Dry ice in a research laboratory sink may cause composite material to crack or the plumbing to freeze.
- Dry ice stored in a refrigerator could cause the thermostat to cycle off.
- Sublimating dry ice expands over 500 times [(1 pound (lb) ice = 8.8 cubic feet (ft^3) of CO_2 gas]. Because of dry ice off-gassing, it should be stored in a container with a loose-fitting cover to avoid pressure build up that could rupture the container.
- Insulated containers containing dry ice, or areas where dry ice is stored should be labeled with a dry ice warning label (Figure 8-16).

Figure 8-16: Dry Ice Warning Label

8.10.1.b. Controls

Some of the controls that can prevent oxygen-deficient atmospheres from occurring include:

- Training personnel on the physical hazards of the gas being used and the compressed gas system.

- Providing a calibrated oxygen-monitoring device when using chemicals that can displace oxygen.
- Verifying that ventilation controls are operating properly to ensure that fresh make-up air is being supplied to the work area.
- Checking cylinder and container safety devices to ensure that there are no leaks.
- Placing signage to warn people about atmospheric hazards.
- Prohibiting the placement of dry ice or cryogenic liquids in cold rooms or walk-in freezers.

8.10.2. Oxygen-Enriched Atmospheres

OSHA defines an oxygen-enriched atmosphere as containing more than 23.5% oxygen. The source of elevated oxygen levels can be an oxygen cylinder leak, oxygen generator, a chemical reaction byproduct, piped-in oxygen gas, or liquid oxygen. When there is too much oxygen in the air, there is a higher potential for materials to combust and burn more easily. Oxygen should not come in contact with petroleum products or other chemicals that can generate heat and auto-ignite.

8.10.2.a.Controls

Some of the controls that can prevent oxygen-enriched atmospheres from occurring include:

- Training personnel before they work with oxygen from a compressed gas supply system or compressed gas cylinders.
- Preventing the use of cryogenic liquid oxygen if possible. If it is not possible, implementing the controls outlined in Section 8.9, Cryogenic Agents: Liquefied Compressed Gas.
- Checking for oxygen leaks in all connections prior to turning on a fixed system or an oxygen gas cylinder.
- Using a calibrated oxygen-monitoring device to detect leaks.
- Posting “No Smoking” signs in areas where oxygen is being stored or used.

8.11. Research Laboratory Equipment Hazards

A partial list of equipment commonly used in research laboratories that pose recognized physical hazards is provided in Sections 8.11.1-8.11.5.

8.11.1. Autoclaves and Steam Sterilizers

Autoclaves are commonly used in research laboratories to decontaminate heat-stable materials by steam sterilization. This process generates pressurized steam within a sealed chamber. The primary hazards of autoclaves are associated with the high pressure, high heat, and steam generated during use. Secondary hazards include potential exposures to infectious agents, contaminated materials, or sharps. Exposure to sharps most often results from handling materials or debris produced by the explosion of improperly filled and sealed liquid containers or equipment failure.

Autoclaves can be safely used when operated and maintained in the manner prescribed by the manufacturer. A regular preventative maintenance cycle should be established and maintenance performed by a qualified person based on manufacturer requirements. The performance of all equipment components must be regularly evaluated, including temperature and pressure gauges, autoclave chamber, door gaskets, safety interlocks, and relief valves. Other aspects for inspection include dedicated electrical power, drain capacity, and venting. Following the failure of a biological indicator, the autoclave should be evaluated to identify and correct the problem. Autoclaves with damaged components or safety controls should be removed from service until repairs are completed.

Training should be provided to research laboratory staff on autoclave operation, research laboratory-specific written SOPs, administrative controls, and appropriate PPE. Some controls to protect staff from physical autoclave hazards include:

- Checking autoclave drain screens for accumulation of debris (clean as necessary) before each run.
- Packaging materials to prevent exposure to sharp objects while loading and unloading the autoclave.
- Filling bags loosely and placing in autoclave-safe plastic or metal trays.
- Loosening caps on containers with liquids to prevent shattering from over-pressurization. Large bottles with narrow necks may also explode if too full of liquid.
- Locking out and tagging out an autoclave that is not in safe working order to prevent accidental use while waiting for repair.
- Ensuring that the autoclave is de-energized and locked out from all energy sources whenever maintenance or repairs are being performed.
- Ensuring that the pressure in the autoclave chamber is near zero before opening the door at the end of a cycle to prevent exposure to steam and shattered glassware.

- Allowing steam to escape and items to cool before reaching inside and removing items from the autoclave chamber.
- Never putting solvents, volatile or corrosive chemicals (such as phenol, chloroform, bleach, etc.), or radioactive materials in an autoclave.
- Wearing proper PPE, including:
    - Laboratory coat.
    - Rubberized apron.
    - Eye protection.
    - Closed-toe shoes.
    - Heat-resistant gloves.
- Establishing a quality assurance program to verify autoclave function on a regular basis.

8.11.2. Centrifuges

The hazards associated with centrifuges are due mostly to the amount of centrifugal energy generated in their operation. Proper operation of a centrifuge relies on balance of the rotor. Balance is achieved by uniform weight of the tubes and proper arrangement within the centrifuge rotor. Operating a centrifuge with unbalanced rotors may result in reduced equipment life, broken tubes, and movement of the centrifuge unit, or even disintegration of the rotor.

Proper centrifuge operation includes clearly defining the safe operating parameters for specific rotors in multiple rotor machines. Centrifuges with multiple rotors and centrifuge adjustments can create the possibility of placing the wrong rotor in a device (such as a rotor from another manufacturer), or operating a rotor outside of its design tolerance. Either of these conditions can result in catastrophic failure. Rotors used beyond the useful lifetime (beyond manufacturer's recommendation) can fail, while unguarded rotors can make contact with the fingers, hands, and clothing of personnel. Staff should never use their hands to slow spinning rotors. When hazardous materials, such as carcinogens, highly toxic, or infectious agents are placed in a centrifuge, precautions (such as using sealed rotors or sealed rotor cups) must be taken to prevent exposure to aerosols or liquids.

A sample SOP for the safe operation of centrifuges is provided as Enclosure 8-4.

For safe operation of centrifuges:

- Ensure that the load is balanced (evenly distributed inside the chamber) and does not exceed maximum loads, filling levels, and maximum sample density for the equipment.
- Operate and maintain the centrifuge according to manufacturer instructions.
- Turn the equipment off immediately if an unusual condition (noise or vibration) occurs.
- Do not use damaged devices or components until inspection, maintenance, and/or repair can be carried out by the manufacturer.
- Ensure that staff is properly trained prior to operation, and training is documented.

8.11.3. Electrophoresis

The presence of high voltage and conductive fluid in electrophoresis equipment can create significant electrical hazards. This equipment can potentially operate at 2000 volts and more than 800 milliamps. A leak in the buffer tank can cause a change in flow of electricity and result in a serious shock. A lethal shock can be delivered by standard electrophoresis units operating at 100 volts and 25 milliamps. The following precautions minimize hazards when working with electrophoresis equipment:

- Using physical barriers (a guard) to prevent accidental contact with energized electrodes or the buffer.
- Using gel chamber lids or covers equipped with safety interlocks.
- Inspecting equipment to ensure that all switches and indicators are functioning.
- Ensuring that all power cords and electrical leads are undamaged and properly insulated.
- Connecting power supplies to GFCI.
- Using warning signs such as “Danger Electrical Hazard” to alert others.
- Ensuring that power supplies have safety features that detect no-load, overload, sudden load change, short circuit, arc or ground leak, etc.
- Turning off power before connecting or disconnecting electrical leads.
- Connecting electrical leads individually with dry, gloved hands, using one hand only.

- Ensuring that leads are securely connected before operating the equipment.
- Never leaving energized equipment unattended.
- Operating equipment away from unintentional grounding points and conductors (e.g., sinks or other water sources, metal plates, jewelry, aluminum foil, pipes, or other electrical/metal equipment).
- Following the manufacturer's instructions while operating electrophoresis equipment.
- Never wearing low hanging metal jewelry or an identification card on a metal chain when working around electrophoresis equipment.

8.11.4. Cold Storage

Cold storage equipment used in research areas includes refrigerators, freezers, walk-in cold rooms, and walk-in freezers.

Research laboratory refrigerators and freezers may have explosion protection, humidity control, and rapid recovery systems to maintain constant temperature during frequent door openings. Ideally, the internal temperature should stay within the set range, which is established based on the contents. It is recommended that a temperature-tracking system (automated or manual) and alarm system be installed to alert staff when freezers or refrigerators deviate from the set range.

Storage of flammable materials in a refrigerator has the potential to cause vapor accumulation and a potential explosion in the presence of a source of ignition (light or compressor motor). Poorly-sealed containers allow the release and accumulation of vapors within the sealed space. Only explosion-proof refrigerators and freezers can be used for storage of flammable materials. Additional information on storing flammables is provided in Chapter 5, Chemical Safety in Research Laboratories. A label stating "Flammable Materials Refrigerator: Keep Fire Away," can identify such refrigerators.

To control hazards associated with cold storage:

- Post appropriate warning signs and labels to identify hazardous contents.
- Do not use compressed gases or hazardous chemicals in walk-in cold rooms and/or freezers.
- Equip walk-in cold room and freezer doors with emergency push handles on the inside.
- Inspect equipment and areas used for cold storage regularly to verify that they are properly labeled/posted and free of surplus items.

- Monitor equipment for excess condensation that can contribute to slippery surfaces and mold.
- Ensure that appropriate PPE is available and used by personnel working in cold storage.

8.11.5. Heating Equipment

Heating equipment is used in research laboratories to support reactions or handle glassware, exclusive of on-demand water heaters. Most research laboratories contain one or more heating apparatus including ovens, hot plates, heating mantles, water baths, oil baths, salt baths, sand baths, air baths, hot-tube furnaces, hot-air guns, and/or microwave ovens. It is preferred that research laboratory-grade equipment be purchased when possible because of built-in safety features.

Hazards associated with heating equipment include burns, electrical shock, and fire.

Heat-related accidents can be prevented by:

- Using heating devices and other electrical equipment away from water sources, emergency eyewashes, and shower stations.
- Ensuring that heating devices have a temperature-limiting controller to prevent overheating.
- Posting caution signs near heat sources stating “Caution: High Temperature.”
- Prohibiting the use of residential or commercial space heaters in the research laboratory, unless they are specifically approved for laboratory use.

8.11.5.a. Ovens

Precautions for working with ovens include:

- Ensuring that ample clearances are maintained around the oven to reduce heat build-up.
- Using ventilated ovens with a single pass-through design to remove hazardous vapors that may be generated. Exhausted air should be vented outside of the building and away from occupied areas and electrical components.
- Using explosion-proof ovens, hot plates, or heat mantles when heating flammable chemicals.

8.11.5.b. Heating Baths

Guidelines for safe usage of heating baths include:

- Locating equipment on a firm, level surface.
- Managing power cords to prevent damage and exposure to water.
- Plugging waterbaths into GFCI outlets.
- Ensuring that heating temperatures are compatible with the materials being heated.
- Prohibiting the use of mercury thermometers.

8.11.5.c. Microwave Ovens

Microwave ovens have unique hazards, including leakage of nonionizing radiation, rapid changes in temperature and pressure, super heating of liquids, arcing, and boil-over. Radiation hazards are addressed in Chapter 9, Radiation Safety in Research Laboratories.

Controls for reducing hazards when using microwaves include:

- Periodically checking for microwave leakage with a microwave leak detector.
- Making sure the entire unit is clean and working properly.
- Prohibiting the use of steel containers in microwaves unless they have a pressure-relief device.
- Removing screw-caps from containers while being microwaved.
- Covering containers with cotton or foam stoppers to maintain sterility and prevent splatters.

8.12. References and Resources

1. 29 CFR 1910, Occupational Safety and Health Standards:
    - 1910.95 Occupational Noise Exposure.
    - 1910.101, Compressed Gases.
    - 1910.103, Hydrogen.
    - 1910.104, Oxygen.
    - 1910.110, Storage and Handling of Liquefied Petroleum Gases.
    - 1910 Subpart I, Personal Protective Equipment.
    - 1910.157, Portable Fire Extinguishers.
    - 1910.301-335, Electrical Safety.
2. Beckman-Coulter Centrifuge Homepage and Calculator.

3. Compressed Gas Association (CGA):

    - CGA P-1-2008, Safe Handling of Compressed Gases in Containers.
    - CGA P-12-2005, Safe Handling of Cryogenic Liquids.

4. NFPA® (Available from the HEFP website):

    - NFPA® 45, Standard on Fire Protection for Research Laboratories Using Chemicals.
    - NFPA® 55, Compressed Gases and Cryogenic Fluids Code.
    - NFPA® 99, Health Care Facilities Code.
    - NFPA® 101, Life Safety Code.
    - NFPA® 704, Standard System for the Identification of the Hazards of Materials for Emergency Response.

5. Stanford University provides guidance and information on purchasing autoclaves.

6. University of California, San Diego, provides an overview of autoclaves.

7. VHA General Safety Guidebook, Chapter 9, Compressed Gases.

8.13. Enclosures and Fact Sheets

Fact Sheets for Research Laboratory Guidebook

The following fact sheets contain quick-reference information relevant to this chapter:

12.1 Compressed Gases
12.2 Cryogenic Agents
12.3 Compressed Gas Storage
12.4 Portable Appliance Electrical Safety

Enclosure 5-1 Additional Toxicology Information

Enclosure 8-1 Sample SOP: Glass Tubing

Enclosure 8-2 Sample SOP: Operating Compressed Gas Systems

Enclosure 8-3 Sample SOP: Safe Handling of Liquid Nitrogen

Enclosure 8-4 Sample SOP: Safe Operation of Centrifuges

Enclosure 8-5 Sample Centrifuge Log Sheet

Radiation Safety in Research Laboratories

9.1. Introduction

The use of radioactive materials in the research setting is a physical hazard that can cause significant health hazards to workers who have excessive exposure. The local Radiation Safety Program must be followed when working with radioactive materials, radiation-generating equipment, and nonionizing radiation. This chapter provides an overview of the Veterans Health Administration (VHA) policy for working with radioactive materials and radiation-generating equipment, hazards of ionizing and nonionizing radiation, and safety practices to protect workers.

The majority of this chapter addresses ionizing radiation produced by radioactive elements called isotopes, with a focus on the hazards and safety issues in the research laboratory. Nonionizing radiation is discussed in detail in Section 9.9, Nonionizing Radiation.

9.2. Radiation Safety Policy Overview

The following section provides a summary of VHA policies, procedures, and responsibilities that pertain to the management of radioactive materials.

The U.S. Nuclear Regulatory Commission (NRC) establishes regulatory requirements for the use of radiation in VHA programs through Code of Federal Regulations (CFR) Title 10. For legal and compliance purposes, radioactive material used for medical or research purposes is defined as byproduct material. VHA ensures compliant acquisition, possession, use, and disposal of radioactive materials and radiation-generating equipment by adhering to the Master Materials License (MML) issued by NRC. Primary implementation guidance on the use of radiation is outlined in VHA Directive 1105.02, Management of Radioactive Materials.

As low as reasonably achievable (ALARA) is the overarching concept in any application involving radiation or radioactive material. Use the smallest amount of the least harmful isotope for the shortest duration possible. VHA is required by the NRC MML to maintain a formal ALARA program and achieve radiation exposures as far below the maximum permissible dose as practical.

9.2.1. The Department of Veterans Affairs (VA) MML

Rather than issuing individual licenses to each facility, VHA has an MML at the administration level. The Under Secretary for Health is the named license official for the MML and establishes policy through VHA Directive 1105.02.

The Under Secretary for Health established the National Radiation Safety Committee (NRSC) to serve as the oversight committee for VA facilities that use radiation. The NRSC maintains and implements the MML through the National Health Physics Program (NHPP). The NRSC issues individual NHPP permits to VHA facilities that allow the local use of radiation-generating equipment, directs the day-to-day implementation of the MML, and coordinates other NRSC activities.

9.2.2. VHA Facility Director

The VHA Facility Director holds administrative responsibility for the safe use of radiation-generating equipment at VHA research facilities in accordance with the MML permit. The VHA Facility Director issues policies that follow NRC and NHPP guidance, while technical support of key staff and local committees constitute the facility Radiation Safety Program.

9.2.3. Subcommittee on Research Safety (SRS)

The SRS is a subcommittee of the Research and Development (R&D) Committee. All research projects involving radiation hazards must be approved by the SRS and then by the R&D Committee using VA Form 10-0398, Research Protocol Safety Survey. The Radiation Safety Committee (RSC) is separate and distinct from the SRS Committee and has facility-wide authority over the use of radiation. Research involving radiation-generating equipment must be approved by the RSC prior to SRS approval.

9.2.4. RSC and Radiation Safety Officer (RSO)

VHA Directive 1105.02 tasks the RSC and RSO jointly with taking all actions necessary to ensure regulatory compliance and the safe use of radiation-generating equipment. The RSO completes day-to-day compliance and monitoring actions with oversight by the RSC. A primary role of the RSC and RSO is to provide oversight for the safe use of radiation-generating equipment by ensuring that occupational and other doses are ALARA, and to ensure a safety-conscious work environment.

The RSC is established by the Facility Director as the administrative body for the safe use of radiation. The RSC is responsible for reviewing and authorizing all proposed uses of radiation-generating equipment and for setting radiation safety policy. *Note: Some facilities may establish additional research oversight committees (Laser Safety Committee, Physical Security Committee, etc.) that may have shared responsibilities with the RSC.*

The RSC and RSO provide local program guidance and coordinate with other radiation safety staff to develop a Radiation Safety Handbook tailored for the unique capabilities and requirements of each facility. Information on current radiation safety program and regulatory issues is provided to VHA through the NHPP intranet website.

Additional RSC and RSO responsibilities include:

- Conducting an annual program review, site inspections, evaluations, and training of authorized users.
- Coordinating the transfer of radiation-generating equipment.
- Investigating spills and suspected overexposures.
- Managing the employee exposure prevention plan and review of occupational and public doses at least every 6 months.
- Providing security oversight of radiation-generating equipment.
- Ensuring the accuracy of sealed-source inventories.

9.2.5. Principal Investigator/Research Laboratory Supervisor

The Principal Investigator and/or Research Laboratory Supervisor are responsible for ensuring that research staff remains compliant with all aspects of the Radiation Safety Program and Research Safety Program. Management responsibilities include:

- Establishing and enforcing standards of practice that prevent personnel and environmental exposures to radiation hazards.
- Ensuring that research laboratory personnel receive appropriate radiation safety training and that the training is documented.
- Mitigating any concerns identified by the RSO during the annual inspection.

The Principal Investigator must provide the following to the RSC and RSO:

- Information regarding lasers, ultraviolet (UV), and radiofrequency radiation in use, including type, quantity, location, energy level, etc.
- Location, inventory, and procedures of radiation-generating equipment.
- Identification of staff working with radiation-generating equipment.

9.2.6. Authorized User

Each individual requesting to work with radiation-generating equipment must complete training requirements and be approved by the RSO to become an authorized user. Projects involving radiation-generating equipment must be approved by the RSC, SRS, and R&D Committee prior to initiation.

9.2.7. Training

The NRC defines radiation workers as individuals who, in the course of their employment, are likely to receive a dose of more than 100 millirem (mrem) of

radiation in a year from byproduct materials. Radiation workers must receive adequate training to protect themselves against radiation and comply with NRC and VHA radiation protection policies regarding security, training, and safety. Radiation workers have the right to ask the NRC to conduct an inspection if they believe safety concerns exist in their working environment.

Research laboratory workers must be trained in the specific hazards associated with the procedures they will be performing in a given protocol. In general, training must describe all known hazards and the required exposure controls. Exposure controls may include ventilation hoods and shielding (engineering controls), use of regulated areas or exposure time limits (administrative controls), or the use of gloves and safety goggles (personal protective equipment). Training and the specific topics covered during each session must be documented.

9.2.8. Common Research Laboratory Citations

The NHPP and/or the NRC may perform periodic on-site inspections to evaluate the facility's compliance with its NHPP permit and regulatory requirements. The RSO should routinely audit user compliance with radiation safety rules and policies. Any corrective actions must be tracked to completion through the RSC.

Some examples of regulatory violations commonly identified during a radiation safety inspection include:

- Failure to restrict access to only trained and authorized personnel.
- Inventory discrepancies of radioactive materials.
- Failure to store or discard radioactive waste properly.
- Failure to complete radiation worker training.
- Obtaining radioactive materials without specific RSC or RSO approval.
- Failure to maintain safety equipment (fume hoods) for proper operation.
- Failure to perform routine radiological surveys of areas and personnel.
- Failure to secure and properly label containers of radioactive material.
- Failure to wear personal radiation dosimetry devices.
- Failure to properly decommission a radiation laboratory prior to reassignment.

9.3. Overview of Basic Radiation Principles

This section provides a general introduction to the basic principles, terms, and types of radiation that may be encountered in a research laboratory. It is intended to provide safety and research personnel with the basic terminology and concepts needed to understand and implement the requirements of the Radiation Safety Program.

9.3.1. Radiation Concepts and Theory

Radiation is a general term used to describe the propagation or movement of energy across distance. The air around us is filled with electromagnetic radiation in the form of light, radio signals, microwave communications from cell phone

towers, x-rays, and gamma rays from space. When radiation carries enough energy to eject or kick an electron from orbit, it is called ionizing radiation. All radiation below this energy level is called nonionizing radiation.

Radiation consists of packets of energy called photons. The terms wavelength and frequency are inversely related terms used to express the magnitude of energy carried by the photon; (high-energy correlates to radiation with a high-frequency and short wavelength). For simplicity, frequency or wavelength is used to describe lower-energy electromagnetic radiation, such as a radio station playing at 101.5 megahertz (MHz) or visible green light at 500 nanometers (nm).

The majority of this section will address ionizing radiation produced by radioactive elements called isotopes, with a focus on the hazards and safety issues in the research laboratory. Nonionizing radiation is discussed in more detail in Section 9.9, Nonionizing Radiation.

Radiation produced during decay is emitted in all directions. If a person is close enough to an unshielded sample, the radiation will interact with their bodies in a process known as radiation exposure. Some of the interactions will lead to deposits of energy within the body (a variable effect that depends on the type of radiation). This results in a radiation dose. As particles and photons interact with matter, the energy is transferred. In a living cell, this extra energy can alter or break chemical bonds in molecules of the cell, causing cell death or, more rarely, permanent genetic change in the cell nucleus.

While it is important to understand the difference between exposure and dose, for the types of radiation produced in a research laboratory, the terms are often interchangeable. Roentgen equivalent man (rem) is the unit used to describe dose with biological effects taken into account.

9.3.2. Types of Radiation

9.3.2.a. Alpha Particles

An alpha particle (symbol α), consists of two neutrons and two protons ejected as a single unit from the nucleus of an unstable atom. The alpha particle is relatively large and heavy but strongly ionizing to electrons in a narrow region around the particle track. Because they are so much heavier than an electron, they do not deviate from a straight path.

The alpha particle steadily loses energy and slows down. The net result is that alpha particles transfer their energy within a short distance and are not very penetrating; a sheet of paper or 3 centimeters (cm) of air is sufficient to completely stop them. Since alpha particles cannot penetrate the outer layer of human skin, they do not present a risk from exposure external to the body. Alpha emitters do present a serious hazard if they are placed in close proximity to cells and tissues, such as the lungs or digestive tract; therefore, special precautions

are taken to ensure that alpha emitters are not ingested, inhaled, absorbed, or injected.

9.3.2.b. Beta Particles

The beta particle (symbol β*)*, is an energetic electron emitted from the nucleus of unstable isotopes. They have a negative charge and are about 8000 times smaller than the alpha particle, allowing deeper penetration. They can penetrate human tissue deep enough to damage living skin cells, resulting in characteristic beta burns. They can be stopped by an aluminum sheet or low-density material, such as Plexiglas®, a few millimeters thick or by 3 meters of air. Beta particles are produced by several important research isotopes such as Carbon-14 (^{14}C), Phosphorus-32 (^{32}P), Phosphorus-33 (^{33}P) and Iodine-133 (^{133}I).

9.3.2.c. Gamma and X-Ray

Gamma and x-ray radiation (symbol γ) are pure electromagnetic energy without charge or mass that interact only minimally with matter. Gamma and x-ray are the most penetrating type of radiation. Gamma rays are emitted from the nucleus while x-rays are released as a result of changes in the outer electron cloud. In general, gamma rays are more energetic. Nearly all unstable isotopes emit some gamma radiation except for pure beta particle emitters, such as ^{14}C and ^{32}P. Attenuation (either through shielding material or absorption within the body) occurs by several different means depending on the energy of the incident photon.

9.3.3. Terms Used to Describe Radioactive Decay

The following definitions are from the NRC website.

Activity: The rate of disintegration (transformation) or decay of radioactive material per unit time. The units of activity (also known as radioactivity) are the Curie (Ci) and the Becquerel (Bq).

Becquerel (Bq): One of three units used to measure radioactivity, which refers to the amount of ionizing radiation released when an element (such as uranium) spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation, or how many atoms in the material decay (or disintegrate) in a given time period. As such, 1 Bq represents a rate of radioactive decay equal to 1 disintegration per second, and 37 billion (3.7 x 1010) Bq equals 1 Ci.

Curie (Ci): One of three units used to measure the intensity of radioactivity in a sample of material. This value refers to the amount of ionizing radiation released when an element (such as uranium) spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation, or how many atoms in the material decay (or disintegrate) in a given time period. As such, 1 Ci is equal to 37 billion (3.7 x 1010) disintegrations per second, so 1 Ci

also equals 37 billion (3.7 x 1010) Bq. A Curie is also a quantity of any radionuclide that decays at a rate of 37 billion disintegrations per second (1 gram of radium, for example). The Curie is named for Marie and Pierre Curie, who discovered radium in 1898.

Half-life: The time required for half the atoms of a particular radioisotope to decay into another isotope. A specific half-life is a characteristic property of each radioisotope. Measured half-lives range from millionths of a second to billions of years, depending on the stability of the nucleus. Radiological half-life is related to, but different from, the biological half-life and the effective half-life.

Radioactive decay: The spontaneous transformation of one radioisotope into one or more different isotopes (known as “decay products” or “daughter products”) accompanied by a decrease in radioactivity (compared to the parent material). This transformation takes place over a defined period of time (known as a “half-life”), as a result of electron capture; fission; or the emission of alpha particles, beta particles, or photons (gamma radiation or x-rays) from the nucleus of an unstable atom. Each isotope in the sequence (known as a “decay chain”) decays to the next until it forms a stable, less energetic end product. In addition, radioactive decay may refer to gamma-ray and conversion electron emission, which only reduces the excitation energy of the nucleus.

9.3.4. Terms Used to Quantify Exposure and Dose

Careful assessment and tracking of dose is required by NRC and VHA to ensure the safety and health of anyone exposed to ionizing radiation. Doses can be expressed in Curies. Other units include:

Roentgen: A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions resulting in a charge of 0.000258 coulombs/kilogram of air under standard conditions. Named after Wilhelm Roentgen, the German scientist who discovered x-rays in 1895.

Radiation absorbed dose (rad): One of the two units used to measure the amount of radiation absorbed by an object or person, known as the “absorbed dose,” which reflects the amount of energy that radioactive sources deposit in materials through which they pass. The rad is the amount of energy (from any type of ionizing radiation) deposited in any medium (e.g., water, tissue, air). An absorbed dose of 1 rad means that 1 gram of material absorbed 100 ergs of energy (a small but measurable amount) as a result of exposure to radiation. The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad.

Roentgen equivalent man (rem): One of the two standard units used to measure the dose equivalent (or effective dose), which combines the amount of energy (from any type of ionizing radiation that is deposited in human tissue), along with the medical effects of the given type of radiation. For beta and gamma radiation, the dose equivalent is the same as the absorbed dose. By contrast, the

dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Thus, the dose equivalent (in rems) is equal to the absorbed dose (in rads) multiplied by the quality factor of the type of radiation [see Title 10, Section 20.1004, 10 CFR 20.1004), Units of Radiation Dose]. The related international system unit is the Sievert (Sv), where 100 rem is equivalent to 1 Sv.

Gray (Gy): One of the two units used to measure the amount of radiation absorbed by an object or person, known as the "absorbed dose," which reflects the amount of energy that radioactive sources (with any type of ionizing radiation) deposit in materials (e.g., water, tissue, air) through which they pass. One gray (Gy) is the international system of units equivalent of 100 rads, which is equal to an absorbed dose of 1 Joule/kilogram. An absorbed dose of 0.01 Gy means that 1 gram of material absorbed 100 ergs of energy (a small but measurable amount) as a result of exposure to radiation.

Sievert (Sv): The international system unit for dose equivalent equal to 1 Joule/kilogram. 1 Sievert = 100 rem. Named for physicist Rolf Sievert.

Note: These definitions are from the NRC website.

9.3.4.a. Occupational Dose Limits

NRC and Occupational Safety and Health Administration (OSHA) have established maximum limits for worker occupational exposure. NRC limits are derived from cumulative internal and external exposures. OSHA limits are more focused on external exposures (skin). The whole body dose cannot exceed 3 rem over 3 consecutive months or 5 rem per year.

9.3.5. Biological Effects of Radiation Exposure

Short exposures to low doses of ionizing radiation are usually clinically insignificant. However, higher exposure time and/or doses may rupture chemical bonds or form new ones, altering molecules, including deoxyribonucleic acid (DNA) sequences. Doses above 100 rem (1 Sv) cause immediate, systemic health effects including nausea, hair loss, and severe damage to the bone marrow and digestive tract. Ionization may also create toxic free radicals that damage cellular components and is known to induce cancer at high doses and high dose rates. An increased risk of cancer has not been demonstrated at low doses (10,000 mrem).

Since rapidly dividing cells are highly sensitive to radiation, special considerations are given to pregnant workers particularly in the first 20 weeks of pregnancy. Genetic effects may appear in an exposed person's direct offspring or may appear several generations later depending on whether the altered genes are dominant or recessive.

9.3.6. Dosimetry and Personnel Exposure Record

Dosimeters are small devices used to measure radiation exposure or dose over a period of time. The dosimeters most commonly used by research laboratory workers are a small piece of film (film badge) within a plastic case and measure whole-body exposures. The results obtained from these devices are retrospective and do not differentiate between acute (brief) and chronic (extended time) exposures.

Whole-body dosimeters can detect x-ray and gamma radiation above 1 mrem and high-energy beta radiation above 10 mrem. It cannot detect radiation emitted from low-energy beta emitters such as Tritium/Hydrogen-3 (^{3}H), ^{14}C, or Sulfur-35 (^{35}S).

Figure 9-1 is a diagram of a Luxel® optically stimulated luminescence (OSL) dosimeter badge.

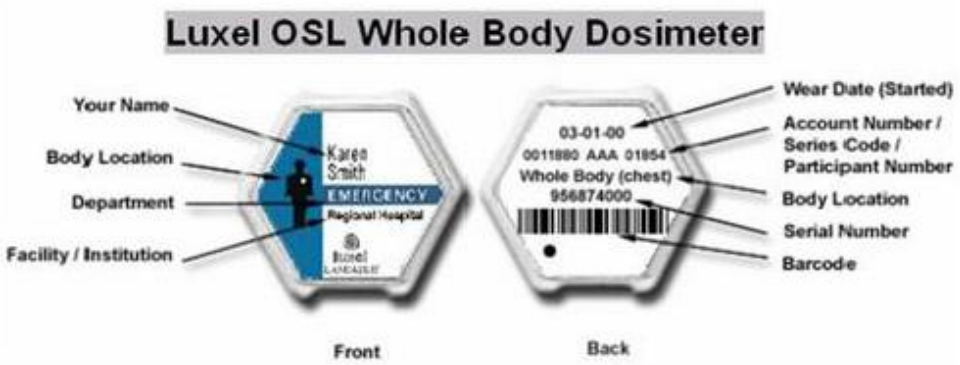

Figure 9-1: Luxel® OSL Whole Body Dosimeter with Labeled Parts (Source: University of Washington, Environment and Health Safety)

A ring dosimeter is used to measure an individual's extremity dose equivalent, usually to the fingers, and is worn on the hand that is most likely to receive the highest radiation exposure.

Safe-use and handling practices of any dosimetry device include:

- Wear dosimetry badges whenever exposures may occur (when working with radiation-generating equipment).
- Do not tamper with the dosimeter or remove the film from the plastic case.
- Notify the RSO immediately if your dosimeter becomes lost or damaged.
- Store dosimeters away from sources of ionizing radiation.
- Do not leave your dosimeter near a heat source or direct sunlight.
- Badges should never be shared.

Under the direction of the RSO, other types of dosimeters may be used for special monitoring applications.

Monitoring records must be maintained according to 29 CFR 1910.1020, Access to Employee Exposure and Medical Records.

9.4. Ionizing Radiation Safety Principles

9.4.1. Hazard Control: Time, Distance, and Shielding

Radiation dose is directly proportional to the time an individual is exposed to a source of ionizing radiation. Time spent handling radiation sources should be minimized as much as possible. Distance is also very important. Less exposure occurs with more distance between a research laboratory worker and a radiation source. For point sources, such as a source vial, doubling the distance from the source reduces exposure by a factor of 4. The use of remote handling tools can significantly reduce dose, especially to fingers.

The use of shielding will reduce the amount and dose of radiation that reaches the body. Sufficient shielding will completely block alpha and beta radiation, while photon radiation penetration follows an exponential decay depending on energy. Use syringe and vial shields, lead blocks, lead foil and leaded glass, or lead-lined syringe carriers to reduce radiation exposure.

Time, distance, and shielding are illustrated in Figure 9-2.

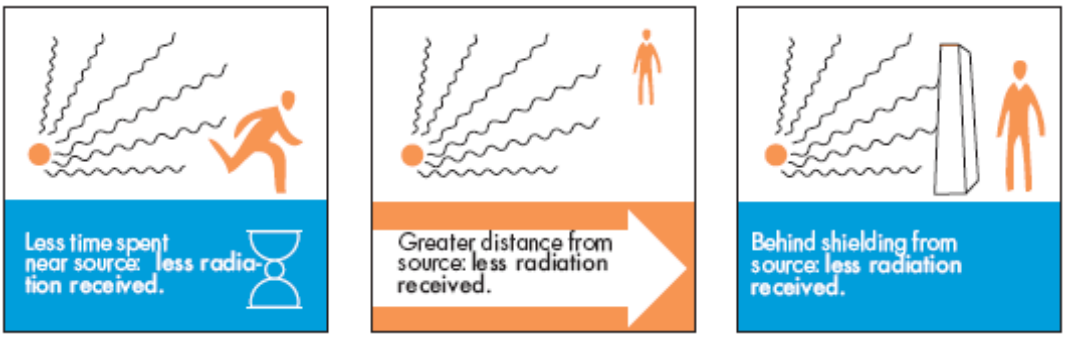

Figure 9-2: Time, Distance, and Shielding Diagrams (Source: NRC, 2011)

9.4.2. ALARA

ALARA is the overarching concept in any application involving radiation or radioactive material. Use the smallest amount of the least harmful isotope for the shortest duration possible. VHA is required by the NRC MML to maintain a formal ALARA program and achieve radiation exposures as far below the maximum permissible dose as practical.

9.4.3. Posting and Labeling

NRC Form 3, Notice to Employees provides information on employee rights and contact information for the NHPP and must be prominently displayed where workers can see it. Posting requirements are listed in VHA Directive 1105.02.

Authorized users must post areas where radiation-generating equipment is used or stored with warning signs bearing the radiation symbol and “CAUTION, RADIATION AREA.” Label the bench, radioisotope containers, disposal sinks, waste containers, and contaminated equipment with radiation caution tape.

9.4.4. Bench Safety

Work involving any radioactive materials must be conducted within a dedicated radiation containment area. Equipment used in the radiation containment area should never be moved or used outside of the research laboratory prior to being surveyed for radioactive contamination.

Specialized equipment is necessary and required for radiation protection. For work with beta-emitters for instance, such specialized equipment could include:

- A portable, hands-free Geiger-Müller (G-M) detector (tube and counter) to screen for contamination of the working area.
- A large, plastic spill tray with raised sides and plastic-backed absorbent disposable liners to contain any spills and prevent contamination.
- Acrylic plastic shielding with a minimum thickness of 1 cm (Figure 9-3).

Figure 9-3: Bench-Top Radiation Shields
(Source: Lab Supply Outlaws)

Best work practices include:

- Avoid working in heavy traffic areas and near doorways.
- Clear the bench area of unnecessary items and cover with an absorbent material with impervious backing.
- Keep contaminated containers and equipment to the rear of the research laboratory bench.
- Use disposable plastic pipette tips, Petri dishes, centrifuge tubes, etc.
- Carefully clean and decontaminate all surfaces after use.

9.5. Management Practices

All research projects involving radiation hazards must be approved by RSC, SRS, and the R&D Committee prior to commencement. The SRS must annually review

all active research protocols involving radiation hazards regardless of funding status or source. Each Facility Director with an NHPP permit must ensure protection of the health and safety of workers and the environment and achieve regulatory compliance.

9.5.1. Ordering, Receipt, and Transfer of Radioactive Materials

Ordering radioactive materials must occur according to established facility protocols in accord with NHPP permit commitments. A procedure for receipt and transfer of radioactive materials should be included in the local Radiation Safety Program.

9.5.2. Inventory

The authorized user must develop a current record and inventory of radioactive material that includes:

- Compliance with the facility Radiation Safety Program. A sample inventory record of isotope use form is provided as Enclosure 9-1.
- Provisions to update the inventory when a product is used or changed.
- Frequency of verifying inventory (type and quantities).
- RSO and/or facility Safety Officer verifies inventories at least semi-annually.
- RSO approval of all acquisitions and uses of radiation-generating equipment.

9.5.3. Security of Radioactive Material

10 CFR 20.1801, Security of Stored Materials and 1802, Control of Material not in Storage covers storage and control of licensed material. These sections state that radioactive material in controlled or unrestricted areas shall be secure from unauthorized removal or access, and that research laboratory workers must control and maintain constant surveillance of radioactive material that is not in storage in a controlled or unrestricted area.

VHA Directive 1105.02 authorizes the RSC and RSO provide local oversight for security of radioactive material.

9.5.4. Transportation of Radioactive Material

Transportation of radioactive material is a complex process that will require coordination with the RSO prior to shipping or receiving any byproduct material. Research laboratory workers should follow the policy in the facility Radiation Safety Program. Several agencies have overlapping authorities for regulating shipments of radioactive materials, including:

- NRC 10 CFR 71, Packaging and Transportation of Radioactive Material.
- The U.S. Department of Transportation (DOT), 49 CFR 173, Subpart I, Class 7 Radioactive Materials.

9.6. Monitoring for Environmental Contamination

For all radionuclides, except ^{3}H, ^{14}C, and ^{35}S, a contamination survey, using a suitably sensitive survey meter for the isotope being monitored, must be performed and documented for each day of radioactive material use and weekly when radioactive material is not in use. Records of all surveys must be maintained to demonstrate radiation levels to RSC and RSO inspectors.

Each portable radiation survey instrument has different detection capabilities, as listed in Table 9-1. There are 3 common categories (G-M, scintillation, and ionization chambers), and selection is based on the type of radioactive material in use. Typically, research laboratories do not use an ionization chamber.

Table 9-1: Survey Requirements with Meter Options for Various Isotopes

Isotope	**Daily-When Radioactive Material is Used**	**Weekly-Conducted Regardless of Work**
	Probe Requirements (mrem/hr)	**Counter/Meter**
^{3}H	Use liquid scintillation counter (LSC) record results in disintegrations per minute	LSC
^{14}C	G-M detector	LSC
^{32}P, ^{33}P, ^{35}S, ^{51}Cr	G-M detector	LSC or G-M survey meter
Iodine-125 (^{125}I)	Nal scintillation detector	Low-energy gamma counter

The following enclosures can be used to record survey results:

- Enclosure 9-2, Sample Inventory Record of Radioactive Material Form.
- Enclosure 9-3, Sample Monthly Research Laboratory Contamination Survey Form.

9.6.1. G-M Detectors

A G-M tube is the sensing element of a G-M detector (Figure 9-4). It is extremely sensitive, and can detect a single beta particle or photon of ionizing radiation. However, the *efficiency*, how well it responds to the radiation of various isotopes, varies widely depending on the energy of the incident radiation. In some instances, the efficiency may be so low as to render the instrument impractical for detection.

Figure 9-4: G-M Detectors with Different Probes
(Sources: Left: Radiation Answers, 2011; Right: Aztec Research, 2011)

When using a hand-held survey meter, move the probe slowly and close to the surface without touching it. Even a tiny amount of contamination will take the probe out of service and may require replacement of the Mylar window. A count rate of more than two times the background typically indicates contamination.

9.6.2. Scintillation Detectors

Scintillation detectors absorb beta or gamma radiation and re-emit the energy as light. They are highly sensitive to the low-energy radiation emitted by some research isotopes. An LSC, (Figure 9-5), is used to detect ^{3}H, ^{14}C, ^{35}S, and ^{125}I and can be used to count contamination removed by wipe samples.

Figure 9-5: Liquid Scintillation Counter (Source: University of Michigan)

A scintillation probe is used on survey meters like the Ludlum 3 for low-energy photons associated with ^{125}I gamma photons.

9.7. Radiological Spill Response

Each local Radiation Safety Program is required to have a spill response procedure based on the type of isotope, energy level, and radiological hazard. When a spill occurs, the first step is to evacuate the area and contact the RSO. The RSO will determine the corrective actions to contain, clean-up/decontaminate, and dispose of the spilled material. Make sure you have the proper supplies and PPE and use a radiation survey meter appropriate for the type and energy of radiation to be surveyed. Follow-up procedures will include

documentation of the incident and medical monitoring of potentially exposed workers.

9.8. Waste Disposal

Disposal of radioactive waste is a regulated activity and must comply with requirements in the local Radiation Safety Program.

As experiments are completed, solid and liquid [low-level radioactive waste (LLRW)] will be generated. This includes all contaminated materials (leftover bench solutions, expired stock vials, and disposable equipment). Decontaminate (render non-radioactive) discarded items, prior to disposal, whenever possible. Radioactive waste must be kept separate from non-radioactive waste and deposited in dedicated unbreakable waste containers with lids, which are labeled and have absorbent material to contain leaks. All radioactive waste must be secured at all times against unauthorized access. Radioactive waste from different sources (experiments) cannot be combined without the RSO's approval.

Waste disposal must be appropriately documented with fill logs and analysis forms completed by the authorized user and attached to each container. Prior to disposal, contamination survey of the exterior of the container must be performed, and the results reported to the RSO at the time of pick-up.

Several options for disposal are available, including decay in storage, discharge to sanitary sewer, or off-site disposal. The type of radioactive material determines the method of disposal used.

9.8.1. Decay-In-Storage

For certain isotopes with a half-life of 6 months or less, disposal by decay-in-storage may be an option. This requires approval by the RSC and will be overseen by the RSO. Although some decay occurs while waste is being accumulated in authorized use locations, the formal tracking, storage, monitoring, and final disposal of waste through the decay-in-storage process is usually performed in a separate, secure facility. Decayed waste can be disposed of as biomedical waste, but all radioactive labels must be obliterated prior to disposal.

Short-lived waste will normally be held for a decay period of 10 radioactive half-lives, after which less than 1/1000th of the original activity remains. If more than one isotope is mixed in the waste, it must be stored for a minimum of 10 half-lives of the slowest decaying component. Table 9-2 provides information regarding minimum decay-in-storage time for specific isotopes.

Table 9-2: Minimum Decay-In-Storage for Specific Isotopes

Isotope	Minimum Decay-In-Storage Time
^{32}P	6 months
^{51}Cr	1 year
^{125}I	2 years
^{35}S	3 years

Additional requirements for decay-in-storage can be found in 10 CFR 35.92, Decay-In-Storage.

9.8.2. Sewer Disposal

Sanitary sewer limits can be locally established and more stringent than 10 CFR 20, NRC Standards for Protection Against Radiation. Sewer disposal involves the discharge of carefully measured and tracked quantities of radioactive liquids into the sanitary sewer system. It is the least expensive method for disposal, but *may only be performed in strict accordance with specific regulatory limits* on both the concentration of radioactivity in a liquid and the total amount of radioactivity that may be released on a monthly and annual basis. Sewer disposal requires approval of the RSC and will be overseen by the RSO.

9.8.3. Off-Site Disposal

Disposal of long half-life radioactive waste by off-site shipment is coordinated by the RSO working with the Green Environmental Management System (GEMS) Coordinator. Waste will be kept in a designated storage area. Contact the RSO to schedule waste pick-ups and prevent accumulation of full containers in work locations. It is extremely important that waste be labeled with the activity and isotope contained in the waste at all times. Every attempt should be made to limit such waste because shipments are expensive, strictly regulated, and must follow rigorous documentation requirements.

Non-compactable materials or items that cannot be incinerated (metal objects and lead shielding materials) should not be put into containers of long-lived dry waste unless absolutely necessary.

9.8.4. Special Cases

9.8.4.a. Mixed Waste

Mixed waste is any combination of hazardous and radioactive waste. The Environmental Protection Agency (EPA) defines hazardous waste as waste that poses a substantial or potential threat to public health or the environment and includes listed waste (lead, mercury, etc.) and categorical waste (ignitable,

corrosive, toxic). Generation of mixed waste should be avoided if possible. The RSO and GEMS Coordinator must be involved in management of mixed waste.

9.8.4.b. Sealed Radioactive Sources

Sealed radioactive sources consist of radioactive material permanently bonded to a surface or sealed within a matrix in a manner that prevents the release or dispersal of the radioactive material under normal use conditions. Certain instruments and manufactured articles contain sealed radioactive sources, including smoke detectors, liquid scintillation counters, and standards used for calibration.

In general, sealed sources are very safe, but periodic leak testing of all sealed sources is required to ensure that the device remains intact. Though the packaging protects radioactive material from physical contact, it does not mean the source is shielded. Some sealed sources produce hazardous levels of radiation, and serious injury has been reported from individuals unknowingly placing them in their pockets. Contact the RSO for specific instructions regarding disposal of sealed sources or surplus equipment that contains radioactive material.

9.8.4.c. Lead Shielding Materials

Lead, often used for shielding materials, is toxic and requires special handling. Lead waste is considered hazardous waste; if disposal is required, lead shielding should be surveyed for contamination. Lead shielding must not be placed into a dry waste container because they cannot be compacted. Do not attempt to decontaminate lead by cutting, heating, or abrasive methods due to the risk of inhalation and ingestion. Contact the RSO or GEMS Coordinator for specific information regarding disposal or decontamination.

9.9. Nonionizing Radiation

9.9.1. Overview

Nonionizing radiation is defined as electromagnetic waves that do not deposit enough energy to break chemical bonds or ionize atoms, such as radio waves [also called radio frequency (RF) radiation], microwaves, infrared (IR), visible, and UV radiation. Lasers that operate within these regions also are a form of nonionizing radiation. The primary effect of exposure to nonionizing radiation is heating within the exposed tissue. Organs with low blood flow (such as eyes and testes) are vulnerable to RF heating because they have a limited ability to dissipate heat.

9.9.2. Important Concepts and Standards

Electromagnetic radiation (EMR) is energy traveling through space with properties of both waves (oscillating electric and magnetic fields) and particles (discrete packets or photons of energy). Depending on the frequency/wavelength, duration of exposure, and intensity or strength of the radiation field, human health effects will vary from essentially none to potentially dangerous.

The Federal Communications Commission (FCC) authorizes and licenses all devices, transmitters, and facilities generating RF radiation and has set a maximum permissible exposure (MPE) guideline for human exposure to RF radiation, exclusive of IR, visible, or UV.

Two terms describe the transfer of energy and biological effects of nonionizing radiation:

- Power density: The power per unit area, expressed in milliWatts per square centimeter (mW/cm^2).
- Specific absorption rate (SAR): The rate energy is absorbed or transferred in tissue, expressed in watts per kilogram (W/kg) or milliWatts per kilogram (mW/kg).

The current exposure limits for RF radiation are established in 29 CFR 1910.97, Nonionizing Radiation, is 10 mW/cm^2 power density (1 mW hour per cm^2 energy density). The FCC has established more stringent standards across that portion of the spectrum where human absorbance is greatest (30-300 MHz).

9.9.3. Biological Effects of Nonionizing Radiation

An SAR above 4 W/kg is generally considered harmful. Cell phones emit 0.2-1.4 W/kg, while some lasers may emit 1300 W/kg or more. The SAR is frequency-dependent. The most restrictive exposure limits are between 30-300 MHz, the range where the human body absorbs RF energy efficiently.

At very high power densities (100 mW/cm^2 or more), tissue damage occurs when energy is transferred to tissue faster than the ability of the body to dissipate or remove the heat. Unshielded exposure to these levels is unlikely in research laboratories.

9.9.4. Microwave Radiation

Microwaves are part of the electromagnetic spectrum with an energy between radio signals and infrared radiation. Some common microwave applications are communication (such as cell phones), satellite transmissions, and food preparation. Research laboratory applications of microwave devices involve post-sectioning processes such as immunolabeling, immunohistochemistry, antigen retrieval, and cell staining. Microwave ovens used in research laboratories should be labeled “For lab use only-no food or drink.”

9.9.5. UV Radiation

Exposure to UV radiation may result in sunburns, corneal burns, fragility, and scarring. Long-term or repeated exposures may result in photoaging (wrinkles, sagging skin, loss of elasticity, and sun spots) or cause damage to DNA in skin cells, resulting in mutations that promote or cause cancer. Some individuals are at higher risk to exposure due to genetics, diet, medications, age, and overall health.

Eye injury is a significant concern because UV light exposure can damage the cornea. Cataracts are also a known health effect from prolonged UV radiation exposure.

UV radiation is used in some research laboratory procedures and is generally a low risk for personnel as long as safety precautions are followed. All equipment (such as transilluminators, UV crosslinkers, UV cabinets, etc.) must be appropriately shielded and should have functional lock-out switches to disable the UV light source and exposure. UV-blocking eye protection should also be used.

9.9.5.a. UV Safety

OSHA has adopted the 2003 guidelines established by the American Conference of Governmental Industrial Hygienists for occupational exposure to UV radiation. UV-generating equipment and the areas where they are used must be labeled (Figure 9-6) and should be designed to contain the hazardous energy. When exposure is possible, skin and eye protection is required. Gloves and long sleeve shirts may be sufficient for hands and arms. Eye protection must be designed to protect against the UV wavelengths produced by the equipment and include side shields.

Figure 9-6: Appropriate Signs for UV-Generating Equipment
(Sources: Left: University of Washington, 2011; Right: University of Farmington, Maine)

9.9.6. Lasers

A laser may be visible or invisible and produces an extremely intense stream of photons that can be focused precisely and loses little energy over significant distances. While useful for delicate medical applications, even momentary eye exposure to the beam without protection may cause blindness.

Any work involving lasers will require review and approval by the Laser Safety Committee or RSC. Laser safety requires comprehensive hazard management and specially-designed controls and protective equipment. Some lasers have high-voltage power sources with significant electrical shock hazards, while chemical lasers use mixtures of highly volatile and often toxic materials. Ventilation, beam control curtains, interlocks, and special protective equipment may be required based on the type and power level of the laser.

9.10. References and Resources

1. 10 CFR 19, Notices, Instructions and Reports to Workers: Inspection and Investigations.
2. 10 FCR 20, NRC Standards for Protection Against Radiation.
3. 10 CFR 20, Medical Use of Byproduct Material.
4. 29 CFR 1910.97, Nonionizing Radiation.
5. 29 CFR 1910.1096, Ionizing Radiation.
6. Centers for Disease Control and Prevention, Workplace Safety & Health Topics, Electric and Magnetic Fields (EMF).
7. Frequently Asked Questions About Health Physicis Based on 10 CFR 20: http://www.nrc.gov/about-nrc/radiation/protects-you/hppos/hppos-qa.html.
8. Memorandum of Understanding Between the U.S. Nuclear Regulatory Commission and the Occupational Safety and Health Administration 10/21/1988: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=MOU&p_id=233.
9. Health Physics Positions (HPPOS) Database.
10. NRC. 2009. NUREG-1556: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1556/.
11. NRC Enforcement Manual.
12. NRC Inspection Manual.
13. NRC Key Guidance Documents.
14. OSHA Standard of Interpretations:
    - 20097, Ionizing Radiation Hazards in the Workplace.
    - 23451, Video Display Terminals (VDTs) and Radiation.
    - 24755, Workplace Exposure Limits for Ultra-Violet Radiation.

15. OSHA Safety and Health Topics, Extremely Low Frequency (ELF) Radiation.

16. VHA Directive 1105.02, Management of Radioactive Materials.

9.11. Enclosures and Fact Sheets

Fact Sheets for Research Laboratory Guidebook

The following fact sheets contain quick-reference information relevant to this chapter:

4.1 Ionizing Radiation and Radioactive Isotope Safety
4.2 Nonionizing Radiation
4.3 Radioisotope Quick Reference, Carbon-14
4.4 Radioisotope Quick Reference, Iodine-125
4.5 Radioisotope Quick Reference, Iodine-131
4.6 Radioisotope Quick Reference, Phosphorus-32
4.7 Radioisotope Quick Reference, Phosphorus-33
4.8 Radioisotope Quick Reference, Tritium/Hydrogen-3
10.4 Storage of Radioactive Materials

Enclosure 9-1 Sample Isotope Use Record Form

Enclosure 9-2 Sample Inventory Record of Radioactive Material Form

Enclosure 9-3 Sample Monthly Research Laboratory Contamination Survey Form

Working Safely with Research Animals

10.1. Veterans Health Administration (VHA) Animal Research

The Department of Veterans Affairs (VA) supports the use of animals in research, teaching, and testing to advance medical treatment for diseases and conditions affecting Veterans. Research involving animals must always be conducted in accordance with ethical and legal standards. VHA Handbook 1200.07, Use of Animals in Research, sets forth the principles and procedures that govern research, testing, and teaching activities involving laboratory animals in the VA, as stated in the United States Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training, from the Public Health Service (PHS) Policy on Humane Care and Use of Laboratory Animals.

An Employee Occupational Health Program (EOHP) is an integral component of the Animal Care and Use Program (ACUP). The EOHP will be unique to each VA facility as determined by the facility design, the animal species utilized, and the inherent hazards of the research conducted. An effective EOHP requires coordination between the Employee Occupational Health Service and the Research Service, the Institutional Animal Care and Use Committee (IACUC); the Subcommittee on Research Safety (SRS); and other administrative offices, such as Human Resources, finance offices, Facilities Management Service, and sometimes affiliate institutions. A comprehensive EOHP includes risk assessment, hazard identification, and control and prevention strategies, such as appropriate facilities, equipment and monitoring capabilities, personnel training, personal hygiene, personal protective equipment (PPE), medical evaluation, and preventative medicine. Knowledgeable health and safety specialists should be involved in risk analysis and hazard identification, as well as in the development of procedures to minimize and/or manage the risks identified. Routine laboratory hazards are covered in Chapter 7, Biological Safety in Research Laboratories, and Chapter 8, Physical Safety in Research Laboratories; this chapter discusses hazards unique to animal research and outlines precautions and standard operating procedures (SOPs) for eliminating or reducing such risks. Detailed information about personnel responsibilities can be found in the National Research Council (NRC) "Guide for the Care and Use of Laboratory Animals."

10.2. VHA Policy Overview

The Facility Director serves as the Institutional Official and is responsible for ensuring that the facility's ACUP is in compliance with regulatory requirements, including:

- Public Health Service Policy on Humane Care and Use of Laboratory Animals (PHS Policy), even if PHS funds are not received.

- United States Department of Agriculture (USDA) Animal Welfare Act (AWA) and Regulations.

- VHA Handbook 1200.07, Use of Animals in Research.

Furthermore, an animal research program must be accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC), either independently or as a component of an affiliate program.

The IACUC is a federally mandated committee responsible for all aspects of animal care and use, including semi-annual evaluations of the ACUP and facilities, and review of research involving live animals.

The Office of Research and Development (ORD) has developed free Web-based training for individuals participating in research involving animals. Training must be completed before beginning work and periodically thereafter as required by VA policy. Required curricula and the frequency of course completion can be obtained on the ORD website.

The VA Animal Component of Research Protocol (ACORP) Form helps to identify potential risks and hazards associated with animal studies so that they can be reviewed and appropriately mitigated prior to initiation.

10.3. Chemical Hazards

Chemicals are routinely used within animal facilities for general cleaning, disinfection, decontamination, and treatments or test articles. For comprehensive information about chemical hazards, refer to Chapter 5, Chemical Safety in Research Laboratories. Before using any hazardous material, refer to the Safety Data Sheet (SDS) for guidance on safe handling procedures and PPE recommendations.

Animals may be exposed to chemicals by topical application, injection, ingestion, or inhalation, which can potentially expose the personnel administering the agent if appropriate controls are not utilized. Guidelines for protective clothing should be determined based on the hazards involved. NIH recommendations for PPE selection are discussed in "Guidelines for Personnel Protection in Animal Facilities."

10.3.1. Tissue Fixatives

Tissue perfusion involves administration of a tissue-fixative agent, such as aqueous formaldehyde solution prepared from paraformaldehyde, into an anesthetized animal. During this procedure, personnel are at risk of being exposed to hazardous levels of vapors and gases; therefore, these procedures should be performed in a chemical fume hood (CFH). Bench-top models equipped with a specially-treated sorbent bed for adsorption may also be used if approved by the SRS. The sorbent must be maintained according to the manufacturer's instructions to function effectively. Downdraft tables incorporating local exhaust

ventilation can be used for small animal perfusions but must be monitored to ensure effectiveness.

10.3.2. Anesthetic Agents

Anesthesia is a state of induced unconsciousness that includes analgesia (pain relief), amnesia (loss of memory), and immobilization. Anesthetics are administered by inhalation or injection and dosed until a physiological effect is reached. Commonly used Injectable anesthetics include Pentobarbital, Ketamine/Xylazine combo, etc. Some anesthetic agents are regulated as controlled substances by the U.S. Drug Enforcement Administration (DEA) and must be properly secured and inventoried.

One disadvantage of inhalant anesthesia is the potential exposure of research laboratory workers to waste anesthetic gas (WAG) that results when anesthetic gas and/or vapors leak into the environment from supply lines, connections, facemasks, endotracheal tubes, etc., during use. Anesthetic gases must be handled properly to ensure a safe work environment. This includes conducting leak tests of the equipment and using scavenging systems to minimize exposure.

Workers exposed to excess amounts of anesthetic gases over short periods may experience symptoms that include drowsiness, headache, nausea, poor judgment, and loss of coordination. Symptoms of long-term over-exposure may include liver, kidney, and (for some agents) reproductive effects.

Inhalant anesthetics are volatile and toxic, and should be stored in a safe area. Agents that are flammable, such as cyclopropane and diethyl ether, must be used with appropriate precautions and approvals because of the high risk of a fire or explosion.

Table 10-1 lists inhalant anesthetics used in animal research.

Table 10-1: Common Inhalant Anesthetic Agents Used in Animal Research

	LIMITS			
Agent	**NIOSH REL**	**ACGIH TLV®**	**Odor Threshold***	**Toxicity**
Enflurane	Ceiling limit 2 ppm (60 minutes)	75 ppm (566 mg/m^3)	Not available	Kidney, ureter, bladder-urine volume decreased.
Halothane**	Ceiling limit 2 ppm (60 minutes)	50 ppm, 404 mg/m^3 TWA	An odor threshold of 33 ppm parts of air has been reported.	Narcotic, central nervous system depression, affects the cardiovascular system, may cause hepatitis, and has reproductive effects in humans.

	LIMITS			
Agent	**NIOSH REL**	**ACGIH TLV®**	**Odor Threshold***	**Toxicity**
Isoflurane	2 ppm ceiling (60 minutes exposure to waste anesthetic gas)	None	Not available	Narcosis, asphyxiant. Target organs: nervous system, heart, liver.
Nitrous Oxide	25 ppm TWA	50 ppm TWA	Not available	Anesthetic effects at high concentrations. Reproductive hazard. Mutagen, teratogen.

NIOSH, National Institute of Occupational Safety and Health; ACGIH®, American Conference of Governmental Industrial Hygienists; REL, recommended exposure limit; TLV®, Threshold Limit Value; ppm, parts per million; TWA, time-weighted average; mg/m^3, milligrams per cubic meters.

*Odor thresholds vary greatly. Do not rely on odor alone to determine potentially hazardous situations.
**When halogenated agents are used in combination with nitrous oxide, exposures should be limited to 0.5 ppm for halothane and other volatile anesthetics and limited to 25 ppm for nitrous oxide.
Note: The Occupational Safety and Health Administration (OSHA) has not established permissible exposure limits (PELs) for these agents.

Investigators and technicians performing animal surgeries with inhalational anesthetics should be identified for inclusion in a formal WAG monitoring program. Representative sampling for ceiling and 8-hour exposure values should be coordinated with the Veterinary Medical Officer (VMO) and the facility Industrial Hygienist during procedures suspected of high exposures. Representative exposure values should be assigned to all program staff and re-sampling conducted when new veterinary procedures are implemented, when equipment is replaced and repaired, or at staff request. The room used for surgery should be maintained at positive pressure to adjacent areas and have adequate ventilation (recommended 10-15 air changes per hour).

OSHA recommends that air sampling for anesthetic gases be conducted every 6 months to measure worker exposures and to check the effectiveness of control measures. Furthermore, OSHA recommends that only the most frequently used agent(s) be monitored because proper engineering controls, work practices, and control procedures should reduce all agents proportionately. The decision to monitor only selected agents could depend on the frequency of their use, the availability of an appropriate analytical method, and the cost of instrumentation. This and additional information can be found in the OSHA guidance document, "Anesthetic Gases: Guidelines for Workplace Exposures." Badge monitors, such as those pictured in Figure 10-1, can give an estimate of a worker's exposure level.

Figure 10-1: Examples of Waste Anesthetic Gas/Vapor Badge Monitors

Passive monitor badges typically have a sample and analysis error of 25% at the 95% confidence level as compared to the OSHA methods presented in Table 10-2.

Table 10-2: OSHA Monitoring Methods

Method	% Error	Media type: Analyte
OSHA Method 166	21%	Passive monitor badge: Nitrous oxide
OSHA Method 29	8%	Dual tube: Halothane and Enflurane
OSHA Method 106	5%	Anasorb 747: Desflurane
OSHA Method 103	6-8%	Anasorb 747 and CMS: Isoflurane, Enflurane and Halothane
Details on these OSHA Methods can be found online at: http://www.osha.gov/dts/sltc/methods/.		

Personnel should be appropriately trained to respond to spills of volatile anesthetic agents. Small amounts of spilled liquid anesthetic agents will evaporate rapidly and may do so before clean-up efforts can be initiated. Due to the volatility of liquid anesthetic agents, rapid removal by suctioning is the preferred method. For large spills, specific cleaning, containment, and disposal procedures will be required, including prompt evacuation of the area and immediately contacting the facility Safety Office. Both enflurane and desflurane are considered hazardous wastes under the Environmental Protection Agency (EPA) regulations because these anesthetic agents contain trace amounts of chloroform, which is a by-product of the manufacturing process. Therefore, any materials that have been used to absorb spilled enflurane or desflurane should be handled as EPA hazardous materials. In contrast, isoflurane and halothane do not contain any other regulated substance, and are not considered to be hazardous

wastes by EPA. Local policies for appropriate disposal procedures should be developed in consultation with safety professionals.

Empty anesthetic bottles are not considered regulated waste and may be discarded with ordinary trash or recycled. However, in all cases, the facility and the waste-handling contractor must adhere to all applicable federal, state, and local regulations.

10.3.3. Anti-Neoplastic and Other Classes of Hazardous Drugs

The NIOSH Working Group on Hazardous Drugs considers any drug to be hazardous if it exhibits any of the following characteristics:

- Carcinogenicity.
- Teratogenicity.
- Reproductive toxicity.
- Organ toxicity at low doses.
- Genotoxicity.

According to the NIOSH List of Antineoplastic and Other Hazardous Drugs in Healthcare Setting, compliance with 29 Code of Federal Regulations (CFR) 1910.1200, Hazard Communication, involves determining whether pharmaceuticals used in research meet these criteria and posting warnings and emergency contact information as appropriate. NIOSH recommends using the following resources to evaluate the hazard potential of each drug:

- Safety Data Sheet.
- Product labeling approved by the Food and Drug Administration (FDA).
- Special health warnings from drug manufacturers, FDA, etc.
- Reports and case studies published in scientific journals.
- Evidenced-based recommendations from other facilities.

Additional guidance on hazardous substances can be found in Chapter 11, Hazardous Materials, of the VHA Industrial Hygiene Guidebook.

Treated animals may pose additional hazards through the excretion of hazardous chemicals in urine or feces. For example, 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP) is used to induce Parkinson's Disease in animals and may cause symptoms of Parkinson's Disease in investigators and animal care workers exposed to the metabolites in the urine and/or feces.

Whenever a hazardous material is to be administered to an animal, the safety requirements must be carefully and systematically reviewed by appropriate oversight subcommittees. The Radiation Safety Officer (RSO) must be involved when radioisotopes are used. Research protocols should state the procedures to follow when handling treated animals and/or soiled caging to limit inadvertent exposure of workers to hazardous metabolites. Special disposal procedures for soiled bedding and animal carcasses may be needed

10.3.4. Controls

10.3.4.a. Engineering Controls

Engineering controls provide primary protection of workers from airborne hazards, such as volatile anesthetics, lyophilized drugs, irritants, etc. Primary engineering controls focus on ventilation and can include CFHs, biological safety cabinets (BSCs) approved for chemical use, anesthetic scavenging systems, and necropsy downdraft tables. Equipment that is used as engineering controls should be included in the facility Preventative Maintenance Program for maintenance and routinely certified or calibrated.

Animals that are being treated with hazardous chemicals can be dosed inside a CFH to minimize worker exposure.

A scavenging system must be used to protect workers by removing WAG from the expired air of anesthetized animals. The two types of scavenging systems are active and passive. Active systems are connected to a dedicated exhaust system and discharged from the building, such as when induction chambers and anesthesia equipment are used inside a CFH. In passive systems, WAG is passed through an appropriate filter canister and released into the room. Absorption canisters work only when vapors actively move through them. Leak testing and maintenance should follow manufacturer instructions. Canisters must be carefully monitored and disposed of properly when the filter is no longer effective.

10.3.4.b. Administrative Controls

Administrative controls help to establish safe work practices and standardized procedures for working with hazardous materials. Procedures should be developed to restrict access to hazards, verify equipment function before each use, use equipment safely, handle hazardous materials properly, prevent and manage spills, and for proper handling and restraint of animals. The user is responsible for checking equipment prior to each use to ensure correct operation. Anesthesia machines and equipment used for aerosol exposures must be checked prior to use to ensure that there are no leaks in the system.

Workers should be trained and verified competent in procedures they are asked to perform. The ORD Web-based training for individuals participating in research involving animals can be accessed online at: http://vaww.research.va.gov/programs/animal_research/.

10.3.4.c. Personal Protective Equipment (PPE)

PPE selection, use, and disposal should be based on a risk assessment and incorporated into local SOPs. Special PPE requirements and disposal methods should be discussed in the protocol prior to starting research. The facility is responsible for providing appropriate PPE and training workers in its proper use and maintenance. PPE should not be worn outside of research areas. The facility

must establish provisions for cleaning, storing, laundering, and discarding soiled, contaminated, or damaged PPE.

10.4. Biological Hazards

The Centers for Disease Control and Prevention (CDC)/National Institutes of Health (NIH) publication, "Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th edition," provides guidance concerning biosafety practices for working with biological agents and the use of these agents in animal research. The infectivity of an agent, the severity of the resulting disease, the nature of disease transmission, the type of the work to be performed, and the origin of the disease (indigenous vs. exotic) are factors that determine the level of containment or biosafety required. Four biosafety levels (BSLs) have been defined by the BMBL, with BSL-1 being the basic level of protection, while BSL-4 is the highest level of containment for agents that cause life-threatening disease for which no preventive or medical treatment is available. The BMBL also provides guidance on the housing and management of experimentally infected vertebrate animals, referred to as Animal Biosafety Level (ABSL). Assignment of an appropriate ABSL is determined by a risk assessment to identify the characteristics of each known or potentially infectious agent, the exposure mechanisms, recommended microbiological practices, safety equipment, and facility controls needed to minimize the risk of laboratory-acquired infections (LAIs). Generally, the BSL for working with infectious agents *in vivo* and *in vitro* are similar. A summary of animal biosafety levels is provided in Table 3, Summary of Recommended Animal Biosafety Levels for Activities in which Experimentally or Naturally Infected Vertebrate Animals are Used, of the BMBL.

NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines) also provide guidance on safe work practices and containment of animal research activities involving recombinant technology.

The design, construction, and operation of BLS-3 and ABSL-3 facilities at VA facilities require prior written approval by ORD. BSL-4 work is prohibited from being performed at VHA facilities.

Guidance on conducting risk assessments and assigning appropriate containment levels is provided in Chapter 7, Biological Safety in Research Laboratories.

10.4.1. Animal Allergies

Laboratory animal allergy (LAA) is a consequence to occupational exposure to animal allergens in a research environment. Any laboratory animal may trigger the development of LAA; however, allergies to mice and rats are the most common because they are the mostly frequently encountered species in research.

Many factors influence the risk of developing sensitivity, including an individual's genetic susceptibility and the intensity, duration, and frequency of exposure. Routes of exposure include direct skin or eye contact, percutaneous exposures

via animal bites/scratches, needlesticks, or antigen contamination of wounds. However, the most common route of exposure to animal allergens is inhalation.

The signs of LAA can vary from simple allergies to severe asthma or anaphylaxis and typically develop within 1-3 years after initial exposure. Risk is increased in workers who have atopy (a genetic predisposition to developing allergies), pre-existing respiratory disease, or other allergies. If left untreated, symptoms can be progressive, making prevention and early recognition important. The condition is also exacerbated by cold, dust, or strong odors, and may persist after the individual is no longer in contact with the allergen.

10.4.2. Zoonoses

Zoonoses refer to animal diseases that can be transmitted from animals to humans. The risk of contracting zoonotic disease will vary with the type of research conducted and the species utilized. The risk of zoonotic disease transmission is lower when working with purpose-bred (commercial vendor) research animals. A detailed list of representative zoonotic diseases is provided by the CDC online at: http://www.cdc.gov/healthypets/diseases/index.html. The National Association of State Public Health Veterinarians document "Compendium of Veterinary Standard Precautions for Zoonotic Disease Prevention in Veterinary Personnel," provides detailed information on zoonotic disease.

10.4.3. Controls

10.4.3.a. Engineering Controls

An animal research facility should be designed to segregate clean areas from contaminated areas. In addition, the ventilation system should incorporate strategies to remove and/or reduce the concentration of airborne contaminants. Consideration should be given to the source of supply air, direction of air flow (least contamination to higher contamination), and number of air changes per hour (ACH).

Other engineering controls include:

- Caging systems, such as individually ventilated cages, that contain or minimize aerosols.
- BSCs.
- Ventilated dumping stations.
- Filtered animal transport containers.
- Mechanical restraint devices to reduce risk of bites and scratches.

10.4.3.b. Administrative Controls

Work practices and research studies should be designed to minimize exposure to biological hazards. Examples include:

- Selecting low-dust bedding materials.

- Adopting husbandry practices that minimize the creation of aerosols.
- Limiting access to animal care areas.
- Providing laundered uniforms.
- Washing hands frequently and avoiding touching faces.
- Dampening cages before dumping or emptying in a high-efficiency particulate air (HEPA)-filtered cage dumping station.
- Employing good house-keeping practices that reduce dust generation.
- Bagging and disposing waste materials promptly and removing soiled containers used for shipment of animals.
- Keeping cages and work areas clean.
- Animal model selection (e.g., species, strain, husbandry requirements, etc.).

LAA is potentially preventable through the use of worker education and implementing measures to reduce allergen exposure. Workers should be trained on the proper use of PPE, containment equipment, personal hygiene, and good work practices.

10.4.3.c. Personal Protective Equipment (PPE)

PPE selection, use, and disposal should be based on a risk assessment and incorporated into local SOPs. Special PPE requirements and disposal methods should be discussed in the protocol prior to starting research. Research workers required to use a respirator must be included in the facility Respiratory Protection Program (RPP). The facility is responsible for providing appropriate PPE and training workers in its proper use and maintenance. PPE should not be worn outside of research areas. The facility establishes provisions for cleaning, storing, laundering, and discarding soiled, contaminated, or damaged PPE.

10.5. Animal-Related Physical Hazards

Physical hazards unique to animal research are discussed in this chapter. Information about other physical hazards commonly associated with any research, including electrical, excessive noise, sharps, and radiation associated with radionuclides or imaging equipment, can be found in in Chapter 8, Physical Safety in Research Laboratories. Ergonomic risk factors, such as awkward or sustained postures, straining or forceful exertion, constant pressure, repetitive motions, vibration exposure or exposure to temperature extremes, are addressed in the VHA Industrial Hygiene Guidebook.

Injuries due to contact with animals vary according to the type of animal and the specific situation. Although dogs, cats, and rodents are the most likely animals to bite, any animal with teeth can and will bite under the right circumstances. Large animals (horses, cows, sheep, goats, etc.) are more likely to kick than bite. Goats and pigs in particular may charge if cornered.

The risk of injury is significantly reduced when personnel are familiar with animal behavior typical of the species, are skilled in using species-specific restraint

techniques and equipment, wear PPE, and use an assistant and/or chemical restraint where appropriate. Avoiding eye contact, speaking calmly, and making the animal aware of your presence before interaction is recommended.

Macaques may inflict bites or scratches that are of particular concern due to the risk of contracting *Macacine herpes virus 1* (Herpes B virus). Workers can also be exposed if injured with sharps and/or equipment that have been contaminated during procedures, such as blood collection, dentals, necropsies, etc., involving macaques. Any injury sustained while working with a macaque should be treated as a medical emergency. CDC information on first aid and treatment for Herpes B can be found online at: http://www.cdc.gov/herpesbvirus/index.html.

10.5.1. Controls

10.5.1.a. Engineering Controls

Engineering controls include restraint devices for animals, safe sharps, sharps disposal containers, and other sharps safety devices, as well as specialized carts and cages for transporting animals.

10.5.1.b. Administrative Controls

Specific safety practices should be customized for the facility and include procedures for:

- Animal restraint and safe handling techniques to prevent injuries.
- Training employees on safe handling of sharps.
- Emergency treatment kits for monkey bites (where applicable).

10.5.1.c. Personal Protective Equipment (PPE)

PPE selection, use, and disposal should be based on a risk assessment and incorporated into local SOPs. Special PPE requirements and disposal methods should be discussed in the protocol prior to starting research. Examples of PPE used to prevent physical injuries include long sleeved laboratory coats, reinforced gloves, steel mesh gloves, etc. The facility is responsible for providing appropriate PPE and training workers in its proper use and maintenance. PPE should not be worn outside of research areas. The facility establishes provisions for cleaning, storing, laundering, and discarding soiled, contaminated, or damaged PPE.

10.6. Medical Surveillance

First aid should be available for any injuries that occur while working with animals. Public Health Service (PHS) Policy on Humane Care and Use of Laboratory Animals requires institutions with animal research programs to establish an Employee Occupational Health Program (EOHP) for workers with exposure to laboratory animals. The VHA Employee Occupational Health Guidebook indicates that every employee who has contact with laboratory animals should be evaluated prior to commencing work with animals and annually thereafter. Special medical evaluations should be performed based on risk assessment, and particular attention should be paid to immunizations, hazard exposure, and the prevention

and development of allergies. This review may take the form of a physical examination or a questionnaire review. A sample Periodic Animal Exposure Questionnaire is provided as Enclosure 39 of the VHA Employee Occupational Health Guidebook.

10.7. Animal Transport

When it is necessary to transport animals into or through public areas, all reasonable means of minimizing exposure of the public to animal body fluids, wastes, and aerosols must be used. Animals must be caged, properly restrained, and concealed or covered during transit. The route used for transportation should avoid public areas.

10.8. Waste Handling

Properly labeled receptacles for waste segregation should be located throughout the animal facility in readily-accessible locations. Medical waste must be collected in leak-proof waste containers equipped with tight-fitting lids.

Soiled animal bedding from healthy animals is considered a solid, non-special waste and may be disposed of in a sanitary landfill if allowed by local policy. Soiled bedding should be collected in a manner that minimizes the release of allergens and bagged and stored in a dedicated waste storage receptacle until removed by a waste management service. Bedding contaminated with biohazardous agents may need to be autoclaved or chemically inactivated prior to disposal. Disposable caging may be an alternative to conventional caging if the unit cannot be properly decontaminated for reuse.

A discarded animal carcass is defined as medical waste by the EPA, but disposal regulations vary by state. This EPA Guideline can be viewed online at: http://www.epa.sa.gov.au/xstd_files/Waste/Guideline/guide_medical.pdf. Infectious animal carcasses can be incinerated on-site (requires special permits) or collected by a licensed contractor. Animal carcasses that are contaminated with hazardous materials that are toxic, carcinogenic, flammable, corrosive, reactive, or otherwise unstable should be placed in properly labeled containers and disposed of as determined by the facility Green Environmental Management System (GEMS) Manager. Dedicated cold storage is required for carcasses, tissues, and body parts that are being held for disposal.

10.9. References and Resources

1. National Research Council:

   - Biosafety in the Laboratory: Prudent Practices for Handling and Disposal of Infectious Materials.
   - Guide for the Care and Use of Laboratory Animals, 8th edition.
   - Occupational Health and Safety in the Care and Use of Research Animals.

2. NIOSH:

- NIOSH List of Antineoplastic and Other Hazardous Drugs in Healthcare Setting.
- Safe Handling of Hazardous Drugs for Veterinary Healthcare Workers.
- Waste Anesthetic Gases-Occupational Hazards in Hospitals.

3. Occupational Safety and Health Act of 1970.

4. Schweitzer IB et al. (2003). Reducing exposure to laboratory animal allergens. Comp Med, 53(5), 487-92. http://www.ncbi.nlm.nih.gov/pubmed/14655990.

5. U.S. Department of Health and Human Services, Public Health Services (2009). Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th edition. Centers for Disease Control and Prevention and the National Institutes of Health.

6. VHA Handbook 1108.01, Controlled Substances (Pharmacy Stock).

7. VHA Handbook 1200.7, Use of Animals in Research.

10.10. Enclosure

Enclosure 10-1 Zootonic Diseases Table

Special Topics: Lasers and Nanoparticles

11.1. Lasers

11.1.1. Introduction

Light amplification by stimulated emission of radiation (laser) is a term used to describe several types of devices that emit extremely intense and focused non-ionizing electromagnetic radiation (or “light”). The light emissions are characterized as a coherent monochromatic (single wavelength) beam with a very low beam spread over distance (divergence).

Lasers emit light either continuously or in pulses. A continuous-wave laser has an output constant over an interval of 0.25 seconds or longer. This type of laser includes diode lasers (laser pointers), argon lasers, krypton lasers, and dye lasers. A pulsed laser delivers its energy in a single burst (pulse) or a series of pulses with each pulse lasting less than 0.25 seconds. Pulsed lasers include Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) and excited dimer (excimer) lasers.

Research laboratory workers working with or near lasers in Veterans Health Administration (VHA) laboratories must understand the special hazards associated with specific lasers, and the engineering controls, administrative procedures, and personal protective equipment (PPE) required for the safe operation of laser devices. The potential for eye injury is a major concern when using lasers and drives the implementation of safe work practices. Other hazards include skin exposure (burns) or fires when working in close proximity to combustible materials.

The American National Standards Institute (ANSI) developed a series of standards to address general and special applications of laser devices or laser systems. ANSI Z136.1, American National Standard for Safe Use of Lasers, and ANSI Z136.8, Safe Use of Lasers in Research, Development, or Testing, provide guidance to protect research laboratory workers using laser devices. The VHA Industrial Hygiene Guidebook has additional information about physiological impacts of laser exposures.

11.1.2. VHA Laser Safety Program (LSP)

Facilities that should establish an LSP when Class 3B and 4 (and possibly 2M) lasers are used and designate a Laser Safety Officer (LSO) when the facility has more than one laser. If there is a diverse application of various types and strengths of lasers, a Laser Safety Committee (LSC) may be necessary to oversee the implementation of the LSP. When lasers are used in research

applications, research staff complies with the facility LSP and may be asked to serve on the LSC.

11.1.2.a. Principal Investigator Responsibilities

The Principal Investigator is responsible for the safe use of lasers in his/her research laboratory and ensures that:

- The engineering and administrative controls and PPE requirements are followed.
- Research involving lasers is approved by the Subcommittee for Research Safety (SRS) and the Research and Development (R&D) Committee prior to initiation and may require approval by the LSO/LSC in accordance with local policies.
- Personnel are properly trained and qualified, and training is appropriately documented.
- Lasers are properly labeled and inventoried, and warning signs are appropriately posted. Laser instruments are serviced and maintained according to manufacturer recommendations.

11.1.2.b. Laser Safety Committee (LSC)

The LSC establishes the facility LSP. Potential members of the LSC include representatives from the SRS, Safety Office, clinical services, and research laboratory workers who use lasers.

Responsibilities of the LSC include:

- Review and approval of research using lasers.
- Provide technical support to the R&D Committee and SRS.
- Establish criteria for equipment and procedures to protect employees and the public.
- Review accidents associated with the use of lasers.
- Monitor the use of lasers, which may include an approval and/or authorization process at the facility.

11.1.2.c. Laser Safety Officer (LSO)

Effective engineering and administrative controls must be implemented for any work involving lasers. Individuals who work with lasers have primary responsibility for ensuring their safe use. When a facility LSO is designated, that individual has primary authority for coordinating all laser safety requirements, including:

- Maintaining a current inventory of laser equipment.
- Identifying all laser users.
- Facilitating baseline and post-exposure physicals for laser users, as needed.
- Maintaining exposure records.
- Establishing an employee training program.

- Implementing a system for reporting and investigating laser-related accidents or injuries.

Note: In the absence of an LSC, the LSO assumes responsibility for implementation of the facility LSP.

11.1.3. Laser Classifications

Lasers are divided into four main classes depending on the power or energy of the beam and the wavelength of the emitted radiation. The general parameters for classification are:

- Laser output energy or power.
- Radiation wavelengths.
- Exposure duration.
- Cross-sectional area of the laser beam at the point of interest.

In the United States, the Center for Devices and Radiological Health (CDRH), a part of the Food and Drug Administration (FDA), and ANSI establish criteria for classifying lasers and laser systems. Internationally, the International Electrotechnical Commission (IEC) 60825 standard is used to classify lasers. The ANSI criteria are designed to harmonize with the IEC and European Standards systems. Laser devices marketed internationally are usually labeled with classifications reflecting both FDA/CDRH and IEC 60825 standards. In each system, lasers are assigned to one of four groups in which lower power and lower injury risk devices are in Class 1 and more powerful the lasers with the greater risk for injury are in higher classes. The Occupational Safety and Health Administration (OSHA) does not currently have a comprehensive laser safety standard and relies on ANSI Z136.1 and FDA/CDRH laser manufacturer requirements. A comparison of FDA/CDRH and IEC laser classes is shown in Table 11-1.

Table 11-1: FDA/CDRH and IEC Laser Classes

FDA Class	IEC Class	Emission Wavelength	Laser Product Hazard	Product Examples
I	1, 1M	Visible/Nonvisible	Considered non-hazardous when used according to manufacturer's instructions. Hazard increases if viewed with optical aids, including magnifiers, binoculars, or telescopes.	• Laser printers. • CD players. • DVD players.
IIa, II	2, 2M	Visible	Hazard increases when viewed directly for extended periods of time or if viewed with optical aids.	• Bar code scanners.

FDA Class	IEC Class	Emission Wavelength	Laser Product Hazard	Product Examples
IIIa	3R	Visible/Nonvisible	Depending on power and beam area, can be momentarily hazardous when directly viewed or when staring directly at the beam with an unaided eye. Risk of injury increases when viewed with optical aids.	• Laser pointers.
IIIb	3B	Visible/Nonvisible	Immediate skin hazard from direct beam and immediate eye hazard when viewed directly.	• Laser light show projectors. • Industrial lasers. • Research lasers.
IV	4	Visible/Nonvisible	Immediate skin hazard and eye hazard from exposure to either the direct or reflected beam; may also present a fire hazard.	• Laser light show projectors. • Industrial lasers. • Research lasers. • Lasers used to perform LASIK eye surgery.
Note: This information reflects normal use conditions and does not apply to situations when the device is being serviced or maintained or is not properly shielded. Note: Class 3R replaced Class 3A.				

Source: FDA, Laser Products and Instruments

A comparison of the laser classification systems is available on the Rockwell Laser Industries website.

11.1.4. Maximum Permissible Exposure (MPE) Limits

Safety thresholds for lasers are expressed in terms of MPE, which is a necessary parameter in determining appropriate eye protection and the nominal hazard zone. The MPE is the maximum level of laser radiation to which a person may be exposed without hazardous effects or biological changes in the eye or skin. The MPE is determined by the wavelength used, associated energy, and the duration of the exposure. ANSI 136.1 contains several tables that summarize the MPE for particular wavelengths and exposure durations. MPE limits are based on the radiation received by the worker from direct beam or reflected beams.

11.1.5. Laser System Hazards and Controls

The hazards of lasers may be separated into two general categories:

- Beam-related hazards to eyes and skin.
- Non-beam hazards, such as electrocution, fire, and chemical.

Injuries to the skin and eye can range from mild burns to irreversible impairment. The biological damage is produced by thermal or photochemical processes. Thermal effects are caused by a rise in temperature following absorption of laser energy. The severity of the damage depends on the energy, wavelength and

duration of the laser beam, and the tissue type. Contact with the energy beam may result in localized vaporization of tissue, and cause a shockwave effect through tissue. Carbon dioxide and infrared lasers are most commonly associated with thermal burns since this wavelength range may penetrate deeply into skin tissue. Beam exposure may also affect cell biochemistry and function due to photon interaction resulting in photosensitization.

Controlling the environment surrounding the laser equipment is important for minimizing hazardous exposures. The standard application of engineering controls, administrative controls, and PPE are also used to contain hazards associated with laser systems.

11.1.5.a. Environmental Evaluation

The laser environment must be designed and assessed to determine adequate control measures, especially for Class 3B and Class 4 lasers. The following should be considered:

- Number and type of lasers or laser systems in the area.
- Ability to restrict access to the laser.
- Access by untrained staff.
- Beam path (open vs. closed) and optics design.
- Location of reflecting objects.

11.1.5.b. Open Beam vs. Closed Beam Hazards

The entire beam may be totally enclosed in some uses of Class 3B and Class 4 lasers. The enclosed beam significantly limits access as opposed to when the beam path is totally open; however, open beam Class 3B and Class 4 lasers present the greatest exposure risk.

11.1.5.c. Nominal Hazard Zone (NHZ)

NHZ is the space within an area in which the level of direct, scattered, or reflected light emitted by the laser exceeds the MPE. Evaluation of the NHZ is important for controlling exposures from Class 3B and Class 4 lasers, especially if the beam is not enclosed, and should be determined with the assistance of the LSO. The NHZ assessment should include:

- Power or energy output.
- Beam characteristics, such as diameter, divergence, path (including reflections), profile, wavelength.
- Pulse repetition frequency.
- Maximum anticipated exposure duration.

An NHZ and MPE Calculation Guide published by the University of Chicago can be accessed online at: http://safety.uchicago.edu/pp/laser/mpe_nhz.shtml.

11.1.5.d. Engineering Controls

Engineering controls are devised to reduce or eliminate exposures to hazardous levels of laser radiation. Commercial laser products are certified by the manufacturer and often incorporate engineering controls. A hazard analysis should be conducted by the Principal Investigator, SRS, and LSO, and additional controls should be implemented to reduce the potential hazards of Class 3B and Class 4 lasers.

Minimal engineering controls should include:

- Protective housing provided by the manufacturer that must remain in place unless alternate controls are authorized by the LSO.
- Service access panels that should only be removed by authorized service personnel.
- Viewing windows and diffuse display screens used during operation or maintenance.
- Collective optics equipped with filters, attenuators, or interlocks to maintain exposure levels below MPE.
- An enclosed beam path fulfilling all the requirements of a protective housing so that no further controls are needed.

In addition to the controls above, engineering controls for Class 3B or Class 4 lasers should also include:

- Protective housings with interlock devices.
- A keyed master switch for disabling the laser when not in use.
- Viewing ports and collecting optics should provide adequate protection to reduce exposure to less than or equal to the MPE at viewing positions (Classes 2, 3R, 3B, or 4).
- Most laser heads are equipped with a permanently attached stopper or attenuator to lower the beam power to the MPE as it exits the housing aperture. Additional beam stoppers may be needed in the beam path to keep the useful beam confined to the experimental area.
- Window protectors that cover windows with absorbing filters, screens, or other barriers.
- Visible or audible area warning devices to warn personnel about activation of laser devices.

11.1.5.e. Administrative Controls

Administrative controls are procedures, work practices, and training that further reduce exposure to hazardous laser radiation and should be implemented before resorting to PPE. Administrative controls include:

- A written LSP that specifies procedures for safe operation of laser/laser systems at the facility.
- Written standard operating procedures (SOPs) (approved by the SRS and LSO) for use, maintenance, and servicing of specific lasers or equipment.
- Designated areas for laser operation based on laser hazard analysis.
- Output emission limitations imposed by the LSO to ensure that radiant energy is maintained at acceptable levels.
- Training and education for all staff involved in the operation and maintenance of lasers.
- Limiting operation, maintenance, and servicing of lasers to authorized individuals.
- LSOs may participate in credentialing authorized individuals.

11.1.5.f. Personal Protective Equipment (PPE)

PPE is used only when other control measures are not practicable or effective. PPE should be selected based on the hazards of the class of lasers and operations conducted. Specific PPE requirements are determined by manufacturer operating procedures and the LSO.

Eye protection designed for the specific wavelength of laser light should be worn when a beam or hazardous reflection could reach the eye. The ability of eye wear to filter the laser beam is expressed in terms of optical density. The PPE manufacturer should list the minimal optical density and wavelength range over which laser eye protection (LEP) is afforded, in accordance with ANSI Z136. LEP frames can be color-coded to correspond to the laser wavelength in use. Although not usually required for Class 2 or Class 3R lasers, LEP is required for operating Class 3B and Class 4 lasers within the NHZ and for long-term (greater than 0.25 seconds) direct viewing. LEP may include goggles, face shields, spectacles, or prescription eyewear (with absorption filter material, reflective coatings, or both). Regular safety glasses or prescription eyewear do not provide adequate protection against viewing the direct beam of a high-powered laser. LEP should be examined prior to each use and discarded if there are any signs of damage.

Thermal burns to the skin are rare and usually require exposure to high energy beams for an extended period of time. Skin protection can best be achieved through engineering controls; however, protective clothing and gloves rated for laser radiation should be considered when working with Class 3B and Class 4 lasers/laser systems. The recommended PPE includes skin covers and or sun-screen (ultraviolet lasers), a flame-resistant laboratory coat, and opaque gloves.

11.1.6. Non-Beam Hazards

Other hazards not related to direct exposure to a laser beam are called non-beam hazards and can be equally dangerous to the user. These include physical hazards (electrical, fire), chemicals (laser dyes, solvents, compressed gases, laser generated air contaminants), biological hazards (airborne bacteria, viruses), and ergonomic concerns (workstation layout, glare). The LSO, in consultation with the SRS and other safety professionals, should evaluate non-beam hazards and implement appropriate controls.

Research laboratory electrical hazards and controls are discussed in Chapter 8, Physical Safety in Research Laboratories.

11.1.6.a. Fire Hazards

Fire hazards are a high risk in oxygen-rich atmospheres, such as surgical areas, and where combustible materials are present. Many Class 4 lasers are capable of igniting combustible materials, making the use of beam stops and shielding material critical. Fire prevention strategies include:

- Ensuring that personnel know what to do in case of fire or explosion.
- Keeping the hot tip of the laser away from combustible items and flammable vapors.
- Maintaining precise control of the laser beam.
- Eliminating reflective surfaces, including jewelry, watches, etc.
- Using flame resistant materials when irradiances greater than 10 watts per square centimeters (W/cm^2) and beam powers greater than 0.5 W.
- Maintaining the laser in stand-by position except when in use.

11.2. Nanoparticles

11.2.1. Introduction

The National Institute for Occupational Safety and Health (NIOSH) is the leading federal agency for conducting research and providing guidance on the occupational safety and health implications and applications of nanotechnology. NIOSH defines nanotechnology as:

> The manipulation of matter on a near-atomic scale to produce new structures, materials and devices. The technology promises scientific advancement in many sectors such as medicine, consumer products, energy, materials and manufacturing. Nanotechnology is generally defined as engineered structures, devices, and systems. Nanomaterials are defined as those things that have a length scale between 1 and 100 nanometers. At this size, materials begin to exhibit unique properties that affect physical, chemical, and biological behavior.

The physical properties of nanoparticles often deviate from those exhibited by larger particles. These changes include colloidal properties, solubility, and catalytic capacity.

11.2.2. Nanoparticle Safety

Information about the specific hazards of nanoparticles is limited; although it is obvious that different types of particles may present different hazards, long term health effects are not completely understood. Appropriate safeguards and safety measures are essential because even materials generally regarded as safe can present unique hazards when formulated into nanoparticles.

Processes with the potential for nanoparticle exposure include:

- Non-enclosed aerosol phase.
- Pouring and mixing liquid media.
- Weighing, blending, and transferring powder.
- Cleaning and maintaining equipment.
- Spill response.

A common route of exposure is inhalation. Air sampling for nanoparticles depends on the particle size and available instrumentation. In many cases, air sampling may not be possible and assessment standards have not been validated; therefore, ventilation controls, such as a chemical fume hood with direct exhaust to the outside, should be implemented whenever aerosolization of nanoparticles is possible.

Functionalized dry nanoparticle products have the highest potential hazard for aerosolization and toxicity; therefore, the potential hazard and functionalization status must be included in the risk assessment. Examples include nanoparticles with attached hazardous drugs, radioisotopes, and metal ions.

Absorption through skin or mucus membranes is also a route of nanoparticle exposure. Because there is minimal data on the penetration of nanoparticles through protective gloves, researchers should ensure that hand protection, such as latex, nitrile (most protective), polyvinyl chloride (PVC), neoprene, etc., is based on specific chemical properties.

Safe working practices are described in the NIOSH document "General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories."

11.3. References and Resources

1. The American National Standards Institute (ANSI):
    - Standard Z136.1, Safe Use of Lasers.
    - Standard Z136.3, Safe Use of Lasers in Health Care Facilities.
    - Standard Z87.1, Industrial Eyewear Impact Standard.
2. International Electrotechnical Commission Standard 60825, Safety of Laser Products.
3. OSHA Technical Manual, Section III, Health Hazards, Chapter 6, Laser Hazards.

4. National Institute for Occupational Safety and Health, Nanotechnology.

5. Environmental Protection Agency, Control of Nanoscale Materials under the Toxic Substances Control Act.

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7. Liu, Z., Tabakman, S., Chen, Z, & Dai, H. (2009). Preparation of carbon nanotube bioconjugates for biomedical applications. *Nature Protocols,* 4, 1372-1381.

8. Klingeler, R.; Hampel, S., & Bernd, B. (2008). Carbon nanotube based biomedical agents for heating, temperature sensoring, and drug delivery. *International Journal of Hyperthermia,* 24(6), 496-505.

9. Srinivasan, C. (2008). Toxicity of carbon nanotubes: Some recent studies. *Current Science,* 95(3), 307-308.

10. U.S. Department of Health and Human Services, Public Health Services. (2007). Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th Edition. Centers for Disease Control and Prevention and the National Institutes of Health.

11. VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories.

12. VHA Handbook 1200.08, Safety of Personnel Engaged in Research.

Research Laboratory Closeout and Decommissioning

12.1. Introduction

Use of research space can change as the needs of the facility and program dictate. When a research laboratory is closed, transitioned to another use, and/or moved, the space must be properly decommissioned. The level or type of contamination that may be present cannot be predicted by a building's age. Decommissioning is a cooperative effort between research laboratory occupants and Veterans Health Administration (VHA) management. Decommissioning complies with 29 Code of Federal Regulations (CFR) 1925 Subpart T, Demolition, along with federal and state Environmental Protection Agency (EPA) requirements. American National Standards Institute (ANSI)/American Society of Safety Engineers (ASSE) Z9.11-2016, Laboratory Decommissioning, recommends a risk-based approach to decommissioning research laboratories. Information related to ANSI/ASSE Z9.11-2016 is presented in this chapter.

12.1.1. VHA Requirements for Research Laboratory Decommissioning

In accordance with VHA Handbook 1058.01, Research Compliance Reporting Requirements, the Principal Investigator is responsible for providing written notification to the Associate Chief of Staff for Research (ACOS/R) and the Subcommittee on Research Safety (SRS) of the intent to vacate research laboratory space. This notification should be made at least 1 month prior to implementation and identify potential hazards. Once notification is given, the ACOS/R must notify the Veterans Integrated Service Network (VISN) Safety Office to coordinate inventory and removal of hazards.

12.2. ANSI/ASSE Z9.11-2016, Laboratory Decommissioning, Overview

ANSI/ASSE Z9.11-2016 divides the decommissioning process into five aspects:

- Scope and needs analysis.
- Risk assessment and characterization.
- Implementation of remediation and mitigation processes.
- Verification.
- Documentation.

The National Institutes of Health (NIH) published "Moving Your Laboratory Safely," which includes model practices for decommissioning. This document can be used as a supplement to ANSI/ASSE Z9.11-2016.

12.2.1. Scope and Needs Analysis

Decommissioning projects are based on the risk assessment of past and future use. The scope of the project, budget, tools, and expertise to ensure that potential

problems and issues are identified are addressed during this phase. The scope and needs analysis includes:

- Project scope.
- Site description and history.
- Points of contact.
- Clearance sampling.
- Research laboratory deactivation documents detailing a description of activities.

12.2.2. Risk Assessment and Characterization

Risk assessments to determine risk levels (Table 12-1) should be conducted by research laboratory workers in consultation with qualified safety professionals during all phases of the project. An approach to historical documentation can be found in Enclosure 12-1, Sample Historical Decommissioning Document.

Table 12-1: Risk Level Characterization

Level	Degree of Risk	Risk Assessment Criteria
1	Low risk, low impact	• Records of previous activities are current and complete. • No significant hazards* used in the past. • Hazards can be readily identified and removed with standard cleaning. • No external resources needed.
2	Low to moderate risk, moderate impact	• Records are adequate, but sampling and direct measurements are needed to assess contamination. • Some significant hazards* used in the past. • Surface and sub-surface cleaning is required, moderate removal efforts are required for localized areas. • Some materials cannot be readily identified by visual inspection alone.

Level	Degree of Risk	Risk Assessment Criteria
3	Moderate to high risk, moderate impact	• Some laboratory records for hazardous materials are incomplete. • History of significant hazard* use. • Widespread sub-surface cleaning required. • Specialized procedures may be needed for significant hazards.* • Extensive sampling is needed to identify hazards. • Contract decontamination/remediation required.
4	High risk, high impact	In addition to Level 3 criteria: • Lack of reliable laboratory records. • Sub-surface and infrastructure decontamination extend beyond the laboratory. • Unanticipated hazards are found during remodeling and demolition.
5	Government agency intervention/oversight required	• Facility records are incomplete and unreliable. • Extensive monitoring is required in all phases including after decommissioning is complete. • May involve infrastructure removal and decontamination.
*Significant hazards include, but are not limited to, chemicals (corrosive, flammable, toxic), reactive chemicals (including reagents that can become shock-sensitive with age), radioisotopes, and significant pathogens, asbestos, mercury, etc.		

12.2.3. Remediation and Mitigation

Remediation is the process of correcting an existing risk, while mitigation addresses specific steps taken to prevent future risk. Decontamination is a process to reduce the risk associated with previous hazardous activities to an acceptable level. If the initial assessment does not show potential contamination, general cleaning procedures will suffice. If hazards are encountered, or a more extensive risk assessment identifies potential contaminants in the areas to be decommissioned, plans for remediation and mitigation should be developed. Each potential contaminant must be identified as to specific risk criteria, the extent of the contamination, whether or not they exceed established criteria, and decontamination requirements.

12.2.4. Verification

The effectiveness of decommissioning is determined by comparing the end results with the original decommissioning plan and should include verification of:

- Decontamination.
- Sample analysis.
- Adherence to the decontamination plan.
- Compliance with federal, state, and local regulations.
- Documentation.

The verification report should be reviewed by the facility Safety staff, Research Service, and the SRS.

12.2.5. Documentation

Thorough documentation must be maintained through all aspects of the decommissioning process and, at minimum, should include the decommissioning plan, final decommissioning report, and a statement of acceptable level of risk for re-occupancy signed by a qualified person, defined by ANSI as “Someone who, by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated ability to solve or resolve problems relating to the subject matter, the work, or the project.”

12.3. Project Phases

ANSI/ASSE Z9.11-2016 divides decommissioning projects into four phases based on risk level. For planning purposes, risk level 3 is assigned to projects pending assessment and until an accurate risk level is assigned. Table 12-2 shows the phases compared to their risk levels and components.

Table 12-2: Phases by Risk Level Assignment

Phase	Risk Level	Phase Components
I	1-5	• Historical review of potential hazards. • Initial inspection. • Considerations for future use. • Report of phase I results. • Development of phase II plan.
II	2-5	• Site sampling and analysis. • Plan for hazard remediation and/or mitigation.
III	3-5	• Implementation of remediation plan. • Final survey to ensure effectiveness.
IV	1-5	• Final report (including submission to regulatory authorities as required).

12.4. Sampling Analysis

A Sampling and Analysis Plan (SAP) should be developed to reduce errors, omissions, and potential liabilities during decommissioning. This plan should be developed by qualified persons and include a Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP).

12.4.1. Field Sampling Plan (FSP)

The FSP should include sampling objectives, sample locations, collection and analytical methods, and data reporting. The FSP must also include a site-specific safety and health plan to ensure worker and public safety during collection and sampling.

12.4.1.a. Field Screening Techniques

There are several methods for evaluating areas (such as in floor surfaces, ceiling tiles, bench tops, drawers, hoods, sinks, drains, and ventilation systems) where contaminants may have accumulated. Detection methods are determined by a qualified person in consideration of chemicals currently and previously used in the space. The SAP should justify the sampling method(s) used and the location of each sample collected. Field screening techniques used to identify additional sampling areas include:

- Visual inspection.
- Direct reading instruments.
- Collection of bulk samples.
- Surface wipe-tests.
- Air sampling.

Field samples must be transferred through a documented chain of custody to a contract laboratory for analysis. Contract laboratories should be accredited for the specific analytical method that is used by a recognized professional organization. The laboratory should be contacted in advance to confirm the methods used in their analyses, as some are accredited for an alternate method.

12.4.1.b. Health and Safety Plan (HASP)

The HASP is required to ensure the safety and health of workers, the public, and the environment. It should include engineering controls, safe work practices and procedures, hazard communication and training requirements, and appropriate personal protective equipment (PPE). Contractors must be informed of site-specific hazards and facility safety policies before starting work.

12.4.2. Quality Assurance Project Plan (QAPP)

The QAPP is a quality assurance plan to ensure that protocols and procedures are followed and the resulting data is accurate. The QAPP may include sampling procedures, calibration procedures, and data validation, as indicated in ANSI/ASSE Z9.11-2016.

12.5. Research Laboratory Close-Out

Prior to remediation, the Principle Investigator ensures that the research laboratory space is cleaned and vacated. This includes the removal of all chemicals, biological and radiological materials, and associated wastes. Clean up requires wiping down work surfaces, including bench tops, biological safety cabinets (BSCs), and chemical fume hood (CFH) surfaces, and other potentially contaminated areas.

12.5.1. Preparation for Close-Out/Decommissioning

The Research Service has ultimate responsibility to ensure that close-out and decommissioning is carried out effectively and safely by the Principal Investigator and staff. The Principal Investigator is responsible for identifying all hazards and ensuring that research laboratory areas and associated equipment are cleaned, disinfected and/or decontaminated, and cleared from the space. A timeline for close-out should be established early in the process, and all procedures must be conducted according to the requirements established local policies prior to vacating the research laboratory. All Department of Veterans Affairs (VA) property must be turned in to the Property Manager.

The Principal Investigator should work with the facility Green Environmental Management System (GEMS) Manager, the facility Industrial Hygienist, and the Radiation Safety Officer (RSO) to ensure proper reallocation and/or disposal of all hazardous materials/wastes and surplus items. It is advisable to retain a hazardous waste disposal contractor with reactive chemical expertise for laboratory clean-out involving peroxided and/or shock-sensitive reagents.

12.5.2. Clean, Disinfect, and Decontaminate Prior to Close-Out

General non-hazardous waste, including empty containers, non-sensitive documents, and disposable materials, should be removed from the space and disposed of in the general waste stream. All research laboratory surfaces and floors should be washed down with warm water and detergent.

Broken glass or unwanted glassware should be disposed of in a cardboard box or other rigid, puncture-resistant container designated for glass. Used pipettes, needles, slides, and razor blades should be placed in an approved sharps container and disposed of in accordance with the facility sharps disposal program.

12.5.2.a. Biological Considerations

A detergent and water solution may be used for general cleaning. However, if the laboratory is designated biological safety level (BSL)-2 or higher, an effective EPA-registered disinfectant must be used to disinfect surfaces or equipment that may be contaminated with live agents or toxins. Any live agents or toxins that are not transferred must be appropriately inactivated prior to disposal. A qualified safety professional (ideally with biosafety experience) should be consulted to ensure that appropriate procedures are followed. Detailed information regarding

biological safety is presented in Chapter 7, Biological Safety in Research Laboratories.

12.5.2.b. Chemical Considerations

The exact method of removing research laboratory materials and equipment will vary depending on the site, materials, and risks involved. The hazardous chemical inventory should be reconciled and availability of required Safety Data Sheets (SDSs) confirmed.

Consult the facility Industrial Hygienist for glove and chemical protective clothing recommendations prior to handling chemicals. Visually inspect chemical containers to determine expiration dates and evaluate the condition of the container for signs of damage, degradation, or corrosion. Chemicals that are expired, unidentified, or enclosed in damaged or corroded containers should be evaluated by the facility GEMS Manager for proper disposal. Visible crystallization of chemicals that are normally liquids can indicate the presence of extremely dangerous shock-sensitive degradation products. These types of chemicals should not be opened or moved until they can be evaluated by a reactive chemical contractor.

Common examples of chemicals that are shock-sensitive when dry include 2,4,6-Trinitrophenol (picric acid) and 2,4- Dinitrophenol.

Peroxide-forming chemicals should be disposed of as hazardous waste prior to expiration. Undated containers of peroxidizable reagents should not be moved or opened until they can be evaluated by a reactive chemical contractor. Common examples of peroxidizable chemicals include Diethylether (ethyl ether); 1,4-Dioxane; and Tetrahydrofurane.

Examples of reagents typically found in organic synthesis labs that can react with water or moisture in the air and ignite include:

- Elemental calcium, lithium, phosphorous, potassium, or sodium.
- Liquid sodium-potassium (NaK) alloy.
- Lithium aluminum hydride.
- Triethyl aluminum.
- Finely divided metals (e.g., aluminum, magnesium).
- Grignard (organometallic) reagents.
- Phosphorous oxychloride.

Individuals who package and/or transport hazardous materials must be properly trained and understand the U.S. Department of Transportation (DOT) hazardous materials shipping regulations. A hazardous chemical transporter is recommended unless the hazardous chemicals are limited and the employees are very familiar with the hazards and proper handling procedures. A sample research laboratory close-out standard operating procedure (SOP) can be found in Enclosure 12-2. Additional information regarding transporting and shipping

chemicals is provided in Chapter 4, Management of Hazardous Chemicals in Research Laboratories.

12.5.2.c. Radiological Considerations

If there is a history of radioisotope use in the laboratory, the RSO must formally decommission and certify the laboratory prior to re-occupancy.

12.5.3. Equipment

All equipment must be cleared, cleaned, and prepared for transportation prior to a research laboratory move. Disposal of mercury-containing instruments (e.g., thermometers) must be coordinated with the facility GEMS Manager. A “free of hazards” certification tag should be attached to all equipment after cleaning/decontamination. Some equipment may be difficult to fully disinfect and/or decontaminate and should be labeled to address the residual hazards. The Sample Form for Declaration of Equipment as Free of all Hazards (Enclosure 7-2) may be used as a tag. Check with the Property Manager to determine whether a property transfer form must be completed.

Refrigerators and Freezers

Refrigerators and freezers must be unplugged, emptied, and thoroughly cleaned inside and out prior to moving. As contents are removed, they should be inventoried and disposed of if they are no longer needed. Units may need to be further decontaminated, disinfected, and/or surveyed depending on the hazards that were stored. Absorbent pads or collection pans should be used to collect water as ice melts when defrosting the unit.

Incubators

Incubators must be unplugged, emptied, disinfected inside and out, and disconnected from the gas line (if applicable) prior to removal or reuse. Incubators with water jackets must be drained. The RSO should be consulted if radioactive materials were used in the incubator.

Compressed Gas Cylinders

Cylinders should be inventoried and scheduled for transfer to central storage or the vendor. Contact the facility GEMS Manager for disposition of unlabeled or unidentified cylinders. Remove regulators or manifolds and replace the safety cap prior to moving.

Cryogenic Tanks

Remove the contents of liquid nitrogen tanks and Dewars prior to moving. This includes biological samples and cryogenic liquids. Proper PPE should be used when working with cryogenic liquids, vapors, and equipment.

Biological Safety Cabinets (BSCs)

The list of biological agents used in each BSC should be reviewed to determine the most effective cleaning and disinfection products and protocols.

All surfaces of each BSC should be initially wiped down, and the contents disinfected and removed, in preparation for a more comprehensive disinfection of the cabinet.

Disinfect inside and outside each BSC (including the sash) with an EPA-registered disinfectant effective for the organisms that were used in the cabinet. Depending on the microorganisms or agents being manipulated, a BSC may require fumigation and removal of the internal high-efficiency particulate air (HEPA) filters before the BSC is relocated or turned in to the Property Manager. Consult a safety professional (preferably with biosafety experience). Fumigation should be performed by a qualified vendor using formaldehyde gas. Allow several days for this process to be completed. Detailed information about BSC care and use is provided in Chapter 7, Biological Safety in Research Laboratories.

Chemical Fume Hood (CFH)
The contents of the CFH should be inventoried and removed for transfer or disposal. Disposal of hazardous materials should be coordinated with the facility GEMS Manager. Disposal of equipment should be coordinated with the Property Manager. The Principal Investigator is responsible for identifying all hazards and working with the facility GEMS Manager and RSO to ensure that the CFH is properly cleaned, disinfected, and/or decontaminated. The hood should be tested by contractors for perchlorates residue and subsequent remediation.

Equipment Containing Mercury
Research laboratory workers should contact the facility GEMS Manager for assistance with equipment that contains or is contaminated with mercury.

Dark Room Equipment
Equipment and tanks used for processing photographic film must be considered as part of the overall decommissioning process. These are often contaminated with hazardous residues and require special disposal procedures, which must be coordinated through the facility GEMS Manager.

Radiation-Emitting Equipment
The RSO must be consulted prior to moving or discarding equipment that has a radioactive source or may be contaminated with radiation. Examples include centrifuge rotors, auto-pipetters, scintillation counters, mass spectrometers, and gas chromatographs.

12.6. Close-Out Inspection

The final step in the decommissioning process is a close-out inspection conducted by Research Service and Safety personnel. When the room has been confirmed to be clear and free of contamination, all hazard warning signs should be removed. Authorization must be obtained before the space can be reoccupied or used for any purpose.

Sample checklists that may be used to document various aspects of the close-out process are provided in Enclosure 12-3.

12.7. Research Laboratory Demolition or Renovation

Decommissioning must be completed prior to demolition or renovation of research laboratory space. Unanticipated hazards, such as asbestos in cement laboratory bench tops and CFHs; perchlorate deposits in the transition ducts above the CFH; sewer lines contaminated with mercury or other heavy metals; metal sink traps contaminated with azides, picrates, etc.; and contamination under floor tiles and behind walls, may be encountered during the demolition process. Facility personnel should anticipate the presence of such hazards during the development of a demolition and/or construction plan.

12.8. References and Resources

1. 29 CFR 1926, Subpart T, Demolition.
2. ANSI/ASSE Z9.11-2016, Laboratory Decommissioning.
3. VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories.
4. VHA Handbook 1200.08, Safety of Personnel Engaged in Research.
5. VHA Handbook 1058.01, Research Compliance Reporting Requirements.
6. Sampling Equipment Decontamination. Modified from Environmental Protection Agency Environmental Response Team, Response Engineering and Analytical Contract, Standard Operating Procedures, Sampling Equipment Decontamination.

12.9. Enclosures

Enclosure 7-2 Sample Form for Declaration of Equipment as Free of all Hazards

Enclosure 12-1 Sample Historical Decommissioning Document

Enclosure 12-2 Sample Standard Operating Procedure: Research Laboratory Close-Out

Enclosure 12-3 Sample Decommissioning Inspection Checklists and Forms

Enclosure 12-4 Recognizing, Evaluating, and Safely Managing Reactive/Unstable Research Laboratory Chemicals

Enclosure 12-5 Sample Hazardous Materials Screening Protocol for Before Demolition of Research Laboratory Space

Environmental Management in Research Laboratories

13.1. Introduction

Veterans Health Administration (VHA) Green Environmental Management System (GEMS) Managers are a valuable resource for Research Service on compliance matters related to environmental regulations. Detailed information on environmental programs can be found in the VHA Green Environmental Management System (GEMS) Guidebook.

13.2. Pollution Prevention and Waste Reduction

Multiple opportunities exist for research laboratories to work with GEMS Managers and the GEMS committee to achieve environmental sustainability goals in the following areas:

- Water conservation.
- Energy conservation.
- Pollution prevention.
- Procurement.
- Environmental management systems.

13.2.1. Water Conservation

Executive Order (EO) 13514, Federal Leadership in Environmental, Energy, and Economic Performance, directs facilities to reduce water consumption intensity by 2% annually through fiscal year 2020, or a total of 26% reduction by fiscal year 2020. Proper selection and management of research laboratory equipment and procedures can contribute to these objectives. For example:

- Control water flow when equipment is not in use.
- Evaluate glassware washing operations to determine if water use can be reduced.
- Use minimum flow rates for water-cooled equipment (e.g., sterilizers and autoclaves) as recommended by the manufacturer.
- Report all leaks immediately.

13.2.2. Energy Conservation

Energy consumption in research laboratories is high due to requirements for lighting, ventilation, and equipment use. Energy conservation opportunities include the purchase and use of electronics that are Energy Star®-qualified or meet the requirements of the Electronic Product Environmental Assessment Tool (EPEAT), and designing energy efficiency into future laboratories. Qualified Energy Star® products can be located by searching the Energy Star® website.

Other practices to conserve energy include:

- Turning off lights, monitors, and equipment when not in use or after hours.
- Closing fume hood sashes when the unit is not in use (if hood operation is not critical to room air balance).
- Using programmable thermostats.

13.2.3. Pollution Prevention

As part of a pollution prevention program, research laboratories should incorporate waste prevention and recycling programs and increase the use of acceptable alternative chemicals and processes. Strategies include:

- Maintaining chemical inventories.
- Ordering the minimum amount of chemicals required for a series of experiments.
- Substitution of a hazardous chemical with a less hazardous chemical.
- Setting up an internal program to allow research laboratories to share chemicals.

Reducing the quantities of hazardous chemicals in a research laboratory also improves safety for research laboratory workers.

The GEMS Manager is responsible for establishing programs for recycling materials, chemicals or equipment. Common items for recycling include batteries, cardboard, paper, glass, metals, plastics, and solvents. Some chemicals and packing materials can also be returned to vendors.

Recycling systems are available to recycle some research solvents, such as xylene, acetone, formalin, and alcohols. These systems reduce the volume of hazardous waste generated and often recover 90 to 95% of many solvents with sufficient purity to allow them to be reused.

13.2.4. Procurement

Facilities are required to purchase items that have recycled content or that can be easily recycled, such as uncoated paper with at least 30% post-consumer fiber. In addition, they must minimize the quantity of toxic and hazardous chemicals. Therefore, Research Service should:

- Purchase the least hazardous chemicals available for a given task.
- Purchase the smallest volumes possible.
- Ensure that equipment is energy-efficient.
- Minimize disposal cost.
- Eliminate the use of elemental mercury.

Tools available to help select alternative chemicals include:

- Massachusetts Institute of Technology Green Chemical Alternatives Purchasing Wizard.

- Environmental Protection Agency's (EPA's) Green Chemistry website.

13.2.5. Environmental Management System

The Department of Veterans Affairs (VA) has adopted the International Organization for Standardization (ISO) 14001, Environmental Management System, for VHA facilities. Periodic inspections allow GEMS Managers to identify areas for improvement. As a best practice, Research Service representatives should be represented on the GEMS Committee to ensure that environmental programs are aligned.

13.3. Non-Hazardous Waste

Non-hazardous solid wastes generated in research laboratories are subject to state and local regulations and VA Property Management requirements related to their collection, storage, and disposal. When possible, recycling should be practiced to reduce waste disposal. Recycling programs can be supported by providing clearly labeled containers that describe the type of material collected. Most facilities arrange to have these wastes disposed of through waste haulers or contractors at a permitted Municipal Solid Waste Landfill or incinerator.

The GEMS Manager can provide support on regulatory requirements and recycling options. Table 13-1 describes the disposition of items used in research laboratories that are not managed as hazardous waste.

Table 13-1: Disposition of Non-Hazardous Items used in Research Laboratories

Category	Description	
Recyclable Items	• Intact, clean glass and plastic (#1 and #2) containers	• Office paper • Cardboard • Metals
Non-Hazardous Waste	• Plate glass • Pyrex • Non-contaminated gloves • Bench paper • Packaging materials • Used foil • Plastic bags • Paper towels • Non-contaminated animal bedding	• Light bulbs • Broken glass chemical containers • Bottle caps • Unused media plates and tubes (with or without media) • Filter flasks • Silica gel (not contaminated with chemical solvents)

13.4. Infectious Waste

Infectious waste can be categorized as biomedical waste or pathological waste. Follow state and local regulations and coordinate with the GEMS Manager for

packaging, handling, and disposal requirements for infections wastes. In addition, infectious wastes are collected in red bags labeled as infectious waste.

Biomedical waste includes waste contaminated by blood, bodily fluids, infectious agents, cultures, soiled personal protective equipment (PPE), and animal bedding from infected animals. Sharps are also considered to be biomedical waste but present unique hazards and require special handling to protect waste handlers from injury. Biomedical waste can be treated (autoclaved, chemical treatment, microwave, etc.) and rendered non-infectious prior to disposal. Waste can be treated on-site, or contained and transported off-site for treatment.

Pathological waste is any waste that contains biological tissues, such as body parts and animal carcasses. Blood and other bodily fluids are not included. If animal infectious waste has any identifiable body parts, it must be disposed as a pathological waste. Pathological waste is typically incinerated.

13.5. Hazardous Waste

Common challenges of managing the generation and disposal of hazardous wastes in research laboratories include the proper classification, storage, labeling, treatment, and disposal of research laboratory wastes, as well as the identification of opportunities to minimize the amount of waste generated. Hazardous waste management is subject to the EPA Resource Conservation and Recovery Act (RCRA) regulations [40 Code of Federal Regulations (CFR) Parts 260-279]. Some states have implemented additional requirements through state RCRA programs.

Examples of research laboratory hazardous waste include:

- Spent solvents.
- Expired chemicals.
- Hazardous chemicals containers.
- Contaminated PPE, absorbents, and spill clean-up material.
- Contaminated biological materials (culture plates, samples, tissues, etc.).

EPA delegated the enforcement of hazardous waste regulations to state environmental protection agencies that may have more stringent regulations. Therefore the hazardous waste management requirements will depend on the type and quantity of waste a facility generates and the state where the facility is located. The facility must establish programs to identify and inventory its waste streams, characterize the waste, identify satellite accumulation areas, and establish procedures for the waste to be disposed or recycled. Waste management activities must be in concert with the GEMS Program. Further details regarding the waste determination process can be found in the VHA Green Environmental Management System (GEMS) Guidebook.

13.5.1. Waste Characterization

As wastes are characterized, facilities must document their research, calculations, and waste stream determinations for inspection by regulatory agencies. In accordance with 40 CFR Subpart 261, Identification and Listing of Hazardous Waste, hazardous wastes must meet the following four criteria:

1. Is the material a solid waste?

   Solid waste is any solid, liquid, or contained gaseous material that is being discarded (40 CFR 261 Parts 261.2 and 261.3). Discarded materials include those that are abandoned, inherently waste-like, or recycled.

   - Laboratory chemicals that are recycled through use or reuse of the expired product may be exempted from the definition.
   - Abandoned materials include those that are disposed; incinerated; and/or accumulated, stored, or treated in lieu of being disposed or incinerated. Research chemicals are abandoned when they can no longer be used and must be discarded as determined by the following criteria:
     - There is no specific use for the chemical and/or there is no inherent value in retaining the chemical at the facility.
     - The chemical is expired.
     - The chemical cannot be transferred to a chemical exchange program or another facility.

2. Does the material qualify for one of the exclusions from the definition of solid or hazardous waste?

   40 CFR 261 includes several exclusions that may apply to wastes generated in research laboratories, including:

   - Domestic sewage operated by permit through the local or regional treatment authority.
   - Radioactive waste managed through the Atomic Energy Act.
   - Waste characterization samples during analysis and transport.
   - Empty containers that once held hazardous waste that meet the definition of empty or RCRA-empty.

3. Is the material a listed hazardous waste?

   Listed wastes are defined in 40 CFR 261, Subpart D, Lists of Hazardous Wastes. Research laboratory wastes appear on lists F (solvents), P (acutely hazardous wastes), and U (toxic). Waste codes F001-F005 apply to waste

streams from the use of certain common organic solvents with specific requirements for inclusion. Chemicals in this category can be found in Table 13-2.

Table 13-2: Hazardous Waste Codes for F-List Wastes

Hazardous Waste Code	Solvent Constituent	
F001	• Tetrachloroethylene • Trichloroethylene • Carbon tetrachloride	• Methylene chloride • 1,1,1-Trichloroethane • Chlorinated fluorocarbons
F002	• Tetrachloroethylene • Trichloroethylene • Methylene chloride • 1,1,1-Trichloroethane • Chlorobenzene	• Ortho-dichlorobenzene • 1,1,2-Trichloroethane • 1,1,2-Trichloro-1,2,2-trifluoroethane • Trichlorofluoromethane
F003	• Xylene • Ethyl acetate • Methanol • n-Butyl alcohol	• Acetone • Ethyl benzene • Methyl isobutyl ketone • Cyclohexanone
F004	• Cresols and cresylic acid	• Nitrobenzene
F005	• Toluene • Carbon disulfide • Pyridine • 2-Ethoxyethanol	• Methyl ethyl ketone • Isobutanol • Benzene • 2-Nitropropane

Source: EPA Hazardous Waste Listings, 2008

The EPA P-list and U-lists designate pure or commercial grade formulations of certain unused, discarded, commercial chemical products as hazardous. Some pharmaceuticals are included. For example, sodium azide (P105) is commonly used as a chemical preservative. When sodium azide acts as a preservative for the active ingredient, it serves an ancillary function and the P105 waste code does not apply. However, a bottle of unused sodium azide that is discarded as a result of research laboratory close-out is considered hazardous waste and carries the P105 listing.

4. Is the material a characteristic hazardous waste?

   40 CFR 261, Subpart C, Characteristics of Hazardous Waste, states that characteristic wastes possess at least one of four characteristics, indicated by the waste codes D001-D043:

- Ignitability (D001).
  Ignitable wastes can be compounds with a flash point of 140 degrees Fahrenheit that readily catch fire and sustain combustion, oxidizers, or ignitable compressed gases.

- Corrosivity (D002).
  Corrosive wastes are acidic (pH less than or equal to 2) or alkaline (pH greater than or equal to 12.5) compounds that readily corrode or dissolve flesh, metal, or other materials.

- Reactivity (D003).
  Reactive wastes are unstable under normal conditions and can readily explode or undergo violent reactions. Toxic fumes, gases, or vapors can also be released when these compounds are heated or mixed with water.

- Toxicity (D004-D043).
  Toxicity characteristic wastes contain regulated constituents that have the potential to generate leachate above regulatory thresholds, as determined by a toxicity characteristic leaching procedure (TCLP) test. VHA policies eliminate and minimize the purchase of mercury-containing equipment and devices, including mercury thermometers.

Research laboratory workers can characterize a waste stream by using their knowledge of the process and waste or sending samples to a laboratory for waste analyses.

13.5.2. The Mixture Rule

It is a common practice for research laboratory workers to combine wastes and generate waste streams that contain several chemicals.

For listed wastes, the mixture rule states that any mixed waste containing a listed hazardous waste is considered a listed hazardous waste. In other words, if a small vial of listed waste is mixed with a larger quantity of non-hazardous waste, the resulting mixture bears the same waste code and regulatory status as the listed component.

A mixture involving characteristic wastes is hazardous only if the mixture exhibits one or more of the four hazardous characteristics. A characteristic waste can be made non-hazardous by treating it to remove its hazardous property(ies) within EPA treatment restrictions. Dilution is *not* an allowable form of treatment, and waste streams should never be mixed without consulting the GEMS Managers. Figure 13-1 is a diagram of the mixture rule.

Figure 13-1: Mixture Rule Diagram

13.5.3. Radioactive Mixed Waste

The Radiation Safety Officer (RSO) and GEMS Manager should be consulted for the disposition of radioactive waste.

40 CFR 266, Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities defines radioactive mixed waste as a waste that contains both RCRA hazardous waste and source, special nuclear, or byproduct material that are subject to the Atomic Energy Act. Mixed waste is subject to RCRA requirements and jointly regulated under the Atomic Energy Act requirements as administered by the Nuclear Regulatory Commission (NRC) and Department of Energy (DOE). Some examples of research laboratory mixed wastes include:

- Used liquid scintillation cocktails that contain xylene or toluene.
- Phenol-chloroform mixtures, resulting from extraction of radiolabeled nucleic acids.
- Aqueous solutions containing chloroform and radioactive material typically found in solutions generated by the neutralization of radioactive trichloroacetic acid solutions.
- Certain gel electrophoresis waste (e.g., methanol or acetic acid containing radionuclides).

Most radioactive mixed waste generated in research laboratories is low-level mixed waste (LLMW), consisting of hazardous waste and low-level radioactive waste (LLRW). LLMW and LLRW should be allowed to decay in a designated storage area until background levels of radiation are reached. After the decay period, the mixed waste is no longer regulated by NRC and should be surveyed

and documented for external radiation prior to releasing it to the chemical waste stream for treatment or disposal under RCRA.

13.6. Satellite Accumulation Areas

Research laboratories may accumulate hazardous waste where the waste is initially generated and collected during daily operations and stored at a clearly defined and labeled satellite accumulation area prior to consolidation in the facility's waste accumulation area. A facility may accumulate up to 55 gallons of hazardous waste or 1 quart of acute (P-Listed) hazardous waste at each satellite accumulation area. Once the 55-gallon or 1-quart limit is exceeded, the waste must be dated and moved to the central accumulation area or shipped directly off-site by the hazardous waste contractor within 3 days. If the waste is not removed from the satellite accumulation area within 3 days, the area must be managed as a central accumulation area and comply with the associated requirements.

State requirements for hazardous waste identification often vary in terms of generator categories, satellite accumulation areas, recordkeeping and reporting, transportation, and training. Some state regulations include additional chemical compounds or waste products, or limit where and how waste is transported and disposed. There is no limit for the number of containers or types of waste in a satellite accumulation area; rather, volume is the limiting factor.

In satellite accumulation areas, each container must be labeled as hazardous waste or with other words to identify the contents, using full chemical names, not abbreviations. Examples of satellite accumulation area labels and other hazardous waste labels are pictured in Figure 13-2. The GEMS Manager should be consulted on proper signage and labels.

Figure 13-2: Sample Satellite Accumulation Site Warning Labels
(Sources: Left, www.HCLCO.com; Right, http://www.mysafetysign.com/Safety-Signs/Hazardous-Waste-Satellite-Sign/SAF-SKU-S-0527.aspx)

Containers at satellite accumulation areas must be in good condition and remain closed except when waste is being added or removed. Containers must be lined

with, or constructed of, materials that are compatible and will not react with the waste in the container. Best practices include placing the waste receptacle in a secondary container for spill control, routinely inspecting satellite accumulation areas, and posting spill clean-up procedures and emergency contact information at each satellite accumulation area. A sample hazardous waste satellite accumulation area checklist is provided in Enclosure 13-1.

13.7. Other Regulated Waste

In addition to hazardous waste, RCRA also regulates used oil and universal waste. These materials may be hazardous, but EPA has streamlined requirements to encourage recycling and proper management.

13.7.1. Used Oil

40 CFR 279, Standards for the Management of Used Oil, defines used oil as any oil that has been refined from crude oil (or synthetic oil) or has been used (i.e., contaminated by physical or chemical impurities). Types of oils included are spent automotive lubricating oils, hydraulic fluids, compressor oils from refrigeration units, and metal working oils. Research laboratory equipment, such as centrifuges, diffusion pumps, and vacuum pumps, may generate used oil. Used oil regulations may vary from state to state, and proper container labeling is required.

13.7.2. Universal Waste

40 CFR 273, Standards for Universal Waste Management, was enacted to ease the hazardous waste management burden and promote the collection and recycling of commonly-generated wastes. Properly labeled containers that remain closed should be available in designated research areas for the collection of universal wastes.

Common universal wastes found in in a research laboratory include:

- Fluorescent light bulbs (high-intensity discharge, neon, mercury vapor, high-pressure sodium, metal-halide).
- Mercury-containing equipment and devices (mercury thermometers, thermostats).
- Batteries (NiCad, lithium).
- Pesticides.

States may adopt more stringent requirements and add or remove wastes from their programs. Since state regulations vary, research laboratory workers should contact the GEMS Manager to see what items are designated as universal waste for their facility.

13.8. References and Resources

1. 40 CFR, Protection of Environment:

- Part 110, Environmental Protection Agency.
- Part 112, Oil Pollution Prevention.
- Part 116, Designation of Hazardous Substances.
- Part 117, Determination of Reportable Quantities for Hazardous Substances.
- Part 260-279, Hazardous Waste Management System, et.al.
- Part 302, Designation, Reportable Quantities, and Notification.
- Part 355, Emergency Planning and Notification.
- Part 370, Hazardous Chemical Reporting: Community Right-to-Know.
- Part 372, Toxic Chemical Release Reporting: Community Right-to-Know.

2. American Chemical Society, Green Chemistry Institute.

3. Carnegie Mellon, Institute for Green Science.

4. Department of Energy, Crosswalk of Sustainability Goals and Targets.

5. Environmental Protection Agency (EPA), Green Chemistry Program.

6. Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management.

7. Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance.

8. Labs for the 21st Century (Labs21).

9. VHA Green Environmental Management Systems (GEMS) Guidebook.

13.9. Enclosures

Enclosure 13-1 Hazardous Waste Satellite Accumulation Area Checklist

Enclosure 13-2 Common Listed Hazardous Wastes used in the Veterans Health Administration

Enclosures

Fact Sheets for Research Laboratory Guidebook

2-1 Sample Job Hazard Analysis: Handling, Transporting, and Storing Cryogens

2-2 Sample Job Hazard Analysis: Use and Maintenance of Electrical Laboratory Equipment

2-3 Sample Job Hazard Analysis: Preparing Samples for Analysis

2-4 Sample Gel Electrophoresis Job Hazard Analysis

2-5 Dermal Exposure Risk Assessment

2-6 Developing a Control Banding Model

2-7 Similarly Exposed Groups (SEGs)

4-1 Sample Research Chemical Hygiene Plan

5-1 Additional Toxicology Information

6-1 General Research Laboratory Design Specifications

6-2 Research Laboratory Exhaust Ventilation

6-3 Additional Fume Hood Types and Information

6-4 Recommended Tests for Different Fume Hood Types

6-5 Research Laboratory Fume Hoods and Hazards Information

7-1 Sample Biological Spill Response Procedures

7-2 Sample Form for Declaration of Equipment as Free of All Hazards

8-1 Sample SOP: Glass Tubing

8-2 Sample SOP: Operating Compressed Gas Systems

8-3 Sample SOP: Safe Handling of Liquid Nitrogen

8-4 Sample SOP: Safe Operation of Centrifuges

8-5 Sample Centrifuge Log Sheet

9-1 Sample Isotope Use Record Form

9-2 Sample Inventory Record of Radioactive Material Form