Research Laboratory Safety Guidebook
Volume 1: Managing Chemical Safety

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Guidance

VHA CEOSH guidebooks are “BEST PRACTICE” resources designed to assist health care facilities implement and enhance programs and more effectively comply with current VA/VHA policy and external regulatory standards. CEOSH guidebooks are **NOT OFFICIAL POLICY**. In accordance with VA Directive 6330, Directives Management System (http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1814), official policy documents include: (1) Directives, which carry the authority to mandate Department- or Administration-wide policies, and (2) Handbooks, which carry the authority to mandate procedures or operational requirements implementing policies contained in directives.

Executive Summary

The Research Laboratory Safety Guidebook was developed as part of the Veterans Health Administration (VHA) Guidebook Series; a multi-volume set of basic safety and health guidebooks to assist VHA facilities in establishing and developing occupational safety and health and environmental compliance 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 Veterans Affairs (VA) Medical Centers within the scope of 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 compliance, assist in developing successful research laboratory safety programs, recognize research laboratory hazards, and reduce exposures.

The guidebook addresses specific application of compliance programs to the research laboratory environment and cross-references to other VHA publications for additional compliance information. The Research Laboratory Safety Guidebook is being published sequentially in three volumes. The first volume focusses on chemical safety. This volume contains an introduction to chemical safety; hazard communication; and associated research laboratory equipment, engineering controls, and best practices. Volume two contains biological, physical, and radiation safety for the research laboratory. Volume three addresses special topics for research laboratory safety programs including 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 Web site or VA's intranet site is provided for additional information or when further information is warranted. Links 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 volume contains 6 chapters as listed below:

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

Several acronyms and abbreviations are used throughout the guidebook; therefore, in order to avoid redundancy in defining them each time they are used, an acronyms and abbreviations list is included in the preface of this guidebook.

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How to Use This Guidebook

The Research Laboratory Safety Guidebook is being published in three volumes. Volume 1: Managing Chemical Safety, is focused on chemical hazards, risk assessment, and engineering controls in the research laboratory. Volume 2 will focus on biological safety, physical safety, and radiation safety. Volume 3 will focus on risk reduction, animal colony safety, environmental management, and decommissioning.

This volume is designed to provide guidance to Department of Veterans Affairs (VA) employees, affiliates, and contractors about requirements, procedures, protocols, and best practices for safety in the research laboratory. Volume 1 also provides information regarding chemical hazards that can affect researchers and other workers. The guidebook will also assist Veterans Integrated Service Network (VISN), facility, and research laboratory staff with a thorough safety hazard evaluation and methods for improving unsafe conditions.

This volume contains six chapters as listed below:

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

At the beginning of each chapter, a general discussion of the topic provides information on compliance with basic requirements. References and enclosures are listed at the end of each chapter. All of the sample documents including medical center policies, standard operating procedures (SOPs), checklists, etc., are included on the CD-ROM and available on the CEOSH Web site at: http://vaww.ceosh.med.va.gov/. Several acronyms and abbreviations are used throughout the guidebook; therefore, in order to avoid redundancy in defining them each time they are used, an acronyms and abbreviations list is included in the preface of this guidebook.

The codes, standards, and regulations referenced in this guidebook were current at the time of publication. However, codes, standards, and regulations are revised on a regular basis. It is VA policy that, unless specifically indicated otherwise, the most recent edition of each code and standard is to be followed. For all applications in this guidebook, use the most recent edition.

Veterans Health Administration (VHA) policy documents (directives, circulars, information letters, etc.) typically include an expiration date. Prior to the expiration date, such documents are generally re-issued with a new expiration date or the information is incorporated into a different current policy document. Occasionally, when VHA policy documents expire, they are not re-issued nor incorporated into a

different current document. Such expired documents that address research laboratory safety issues should be considered best practice guides.

CD-ROM Instructions

The CD-ROM has an electronic version of the Research Laboratory Safety Guidebook Volume 1: Managing Chemical Safety. You can view these files directly from the CD-ROM with no installation, or copy them to your hard drive. The complete book can also be found on the CEOSH Web site (http://vaww.ceosh.med.va.gov).

The CD-ROM contains the following files:

File	Description
Research Laboratory Safety Guidebook Volume 1: Managing Chemical Safety	This folder provides access to this volume of the Research Laboratory Safety Guidebook.
Enclosures	This folder contains all of the enclosures.
Printer-Friendly Version	This folder contains guidebook information as it appears in printed form. It can be used for printing selected information or full chapters at once.
Visit CEOSH Web site	This will take the user to the CEOSH Web site, from which all guidebooks can be accessed

The CD-ROM should start automatically when inserted into the CD Drive. If it does not start automatically, right-click on Start, select Explore, select CD Drive, select Autorun.exe to activate the CD options.

For Windows XP users:

If your internet explorer options automatically block active content, you will need to temporarily allow blocked content by right clicking on the information bar and selecting “Allow Blocked Content”. At the security warning dialog box, select “Yes” to allow content.

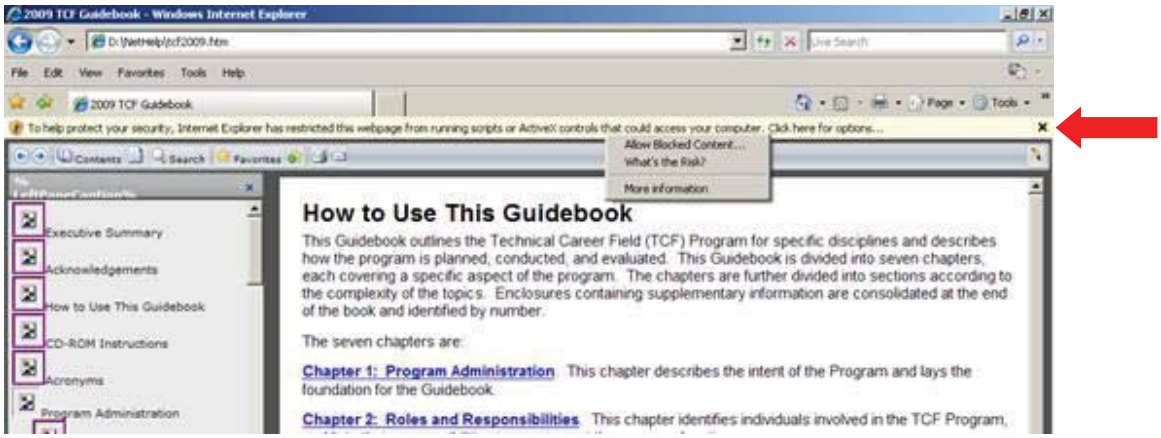


Figure 1: Internet Explorer screen shot enabling ActiveX controls

For Windows 7 users:

The CD-ROM should start automatically when inserted into the CD Drive. If it does not start automatically, right-click on the Windows Start Orb , select Explore, select CD Drive, select Autorun.exe to activate the CD options.

If your Internet Explorer options automatically block active content, you will need to allow blocked content by selecting “Yes” at the security warning dialog box.

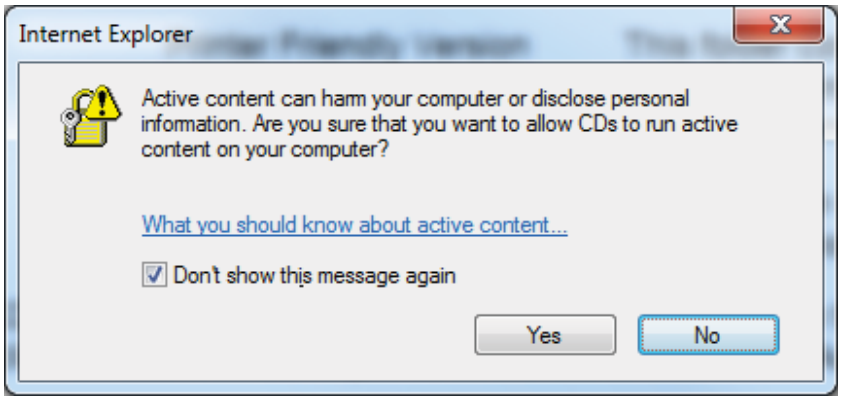


Figure 2: Security Warning Dialog Box

You will need to select “allow blocked content” on the scripts or ActiveX controls warning bar that appears at the bottom of the screen.

Figure 3: Internet Explorer ActiveX Controls Warning Bar

Update Listing

The following listing identifies online updates since the initial publication of Volume 1: Managing Chemical Safety, of the Research Laboratory Safety Guidebook. It is designed to assist the reader in verifying the most current information available.

Update Number	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
µm	micrometers
2-ME	2-Mercaptoethanol
ACGIH®	American Conference of Governmental Industrial Hygienists
ACH	Air Change Per Hour
ACM	Asbestos-Containing Material
ACOS	Associate Chief of Staff
ACUP	Animal Care and Use Programs
AED	Automated External Defibrillator
AFFF	Aqueous Film-Forming Foam
Ag_2O	Silver Oxide
$AgNO_3$	Silver Nitrate
AIHA	American Industrial Hygiene Association
ALK	Alkali
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
ASTM	American Society for Testing & Materials
ATSDR	Agency for Toxic Substances & Disease Registry
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
Br_2	Bromine
BrO_4	Bromate
BSC	Biological Safety Cabinet
BSL-3	Biosafety Level 3
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_5OH	Phenol
C_6H_6	Benzene
$C_6H_5CH_3$	Toluene

CAS	Chemical Abstracts Service
CAV	Constant Air Volume
CDC	Centers for Disease Control and Prevention
CEOSH	Center for Engineering & Occupational Safety and Health
CFH	Chemical Fume Hood
cfm	Cubic feet per minute
CFM	Office of Construction & Facilities Management
CFR	Code of Federal Regulations
CH_2CL_2	Methylene Chloride
CH_3-Hg-CH_3	Dimethyl Mercury
CHO	Chemical Hygiene Officer
CHP	Chemical Hygiene Plan
ClO	Hypochlorite
ClO_2	Chlorite
ClO_3	Chlorate
ClO_4	Perchlorate
CMOP	Consolidated Mail Outpatient Pharmacy
CNS	Central Nervous System
COR	Corrosive
COR	Contracting Officer's Representative
COS	Chief of Staff
CPR	Cardiopulmonary Resuscitation
CR(IV)	Chromium
Cr(VI)	Chromium Hexavalent
$Cr_2O_7^{2-}$	Dichromate
CRADO	Chief Research and Development Officer

CrO_3	Chromium trioxide
CrO_3	Chromium (VI) Trioxide
CrO_4^{2-}	Chromate
CRY or CRYO	Cryogenics
DBCP	dibromochloropropane
DES	diethylstilbestrol
DHHS	Department of Health and Human Services
DNA	Deoxyribonucleic Acid
DOE	Department of Energy
DOL	Department of Labor
DOT	Department of Transportation
DTLVS	Documentation of the Threshold Limit Values for Substances
EHS	Environment, Health, and Safety Office
EMS	Environmental Management Service
EO	Executive Order
EOC	Environment of Care
EPA	Environmental Protection Agency
EtBr	Ethidium Bromide
EtO	Ethylene Oxide
F_2	Fluorine
FAA	Federal Aviation Administration
FAQ	Frequently Asked Questions
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
FV	Face Velocity
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)
GM	Geometric Mean
GSD	Geometric Standard Deviation
GTA	Glutaraldehyde
H_2CrO_4	Chromic Acid
H_2O_2	Hydrogen Peroxide
H_2SO_4	Sulfuric Acid
HAC	Hazardous Air Contaminant
HAZWOPER	Hazardous Waste Operations and Emergency Response
HCHO	Formaldehyde
$HClO_4$	Perchloric Acid
HCP	Hazard Communication Program
HCS	Hazard Communication Standard
HDPE	High-Density Polyethene
HEPA	High-Efficiency Particulate Air
HF	Hydrofluoric Acid
Hg	Mercury

HHS	Health and Human Services
HIO_4 or H_5IO_6	Periodic Acid
HMIS	Hazardous Materials Identification System
HMR	Hazardous Materials Regulations
HMTA	Hazardous Materials Transportation Act
HNO_3	Nitric Acid
HP	High Performance
HPLC	High-Performance Liquid Chromatography
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
IO_3	Iodate
IO_4^-	Iodic
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
KIO_3	Potassium Iodate
$KMnO_4$	Potassium Permanganate
KNO_3	Potassium Nitrate
kPa	kilopascal
LC	Lethal Concentration
LD	Lethal Dose
LEL	Lower Explosive Limit
LEV	Local Exhaust Ventilation
LFL	Lower Flammable Limit
LVMP	Laboratory Ventilation Management Program
MC	Methylene Chloride
mg	milligrams
mg/m^3	milligrams per cubic meters
ml	milliliters
mm	millimeters
mmHg	millimeters of mercury
MnO_4^-	Permanganate
MOT	Materials of Trade
MOU	Memorandum of Understanding
MSDS	Material Safety Data Sheet
MW	Molecular Weight
N_2O_x	Nitrogen Oxide
$Na_2Cr_2O_7$	Sodium Dichromate

$Na_2S_2O_8$	Sodium Persulfate
NaClO	Sodium Hypochlorite Solution
$NaIO_3$	Sodium Iodate
$NaIO_4$	Sodium Periodate
$NaMnO_4$	Sodium Permanganate
$NaNO_2$	Sodium Nitrite
NCI	National Cancer Institute
NDZ	No Diffuser Zone
NFPA®	National Fire Protection Association
NF_x	Nitrogen Fluorides
NH_4NO_3	Ammonium Nitrate
NIH	National Institutes of Health
NIOSH	National Institute of Occupational Safety and Health
nm	nanometer(s)
NMR	Nuclear Magnetic Resonance
NO_3^-	Nitrate
NOEL	No Observable Effect Level
NRC	Nuclear Regulatory Commission
NSF	National Sanitation Federation
NTP	National Toxicology Program
O_2	Oxygen
OBA	Office of Biotechnology Activities
OCAMES	Office of Capital Asset Management and Engineering Support
$OCH(CH_2)_3CHO$	Glutaraldehyde
OEL	Occupational Exposure Limit
OH	Occupational Health

OIG	Office of the Inspector General
-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
PHS	Particularly Hazardous Substance
PPE	Personal Protective Equipment
ppm	parts per million
psi	pounds per square inch
PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride
PVS	Polyvinyl Steel
R&D	Research and Development
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
rDNA	Recombinant DNA
REL	Recommended Exposure Limit
RIPP	Research Information Protection Program
RPSS	Research Protocol Safety Survey
RSC	Research Safety Coordinator

RSO	Radiation Safety Officer
$S_2O_8^{2-}$	Persulfate
SA	Simple Asphyxiant
SAFE	Safety Automated Facility Evaluation
SDS	Safety Data Sheet
SEG	Similarly Exposed Group
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.
TAB	Test, Adjustment, and Balance
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 GHS	United Nations' Globally Harmonized System (of Classification and Labeling of Chemicals)

USDA	United States Department of Agriculture
UV	Ultra Violet
VA	Department of Veterans Affairs
VAMC	VA Medical Center
VAV	Variable Air Volume
VBE	Ventilated Balance Enclosure
VE	Variable Exhaust
vfag	average face velocity
VHA	Veterans Health Administration
VISN	Veterans Integrated Service Network
VP	Vapor Pressure
~~W~~	Reacts Violently with Water
~~W OX~~	Reacts Violently with Water and Oxidizers
WG	Water Gage
WHO	World Health Organization
WOC	Without Compensation

1. 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 medical center 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), Occupational Health (Employee 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 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. VAMC 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), United States Department of Agriculture (USDA), and the Department of Labor (DOL).

ORO is comprised of a central office and regional offices. The 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 local Safety Office and the 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 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 VAMC may share an R&D Committee with another VAMC, 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 DNA (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 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 non-ionizing 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 (RPSS) 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. Occupational Health (OH) Services

OH services are integral to research safety and health programs. Although not a requirement, OH participation on the SRS can enhance the overall safety program. OH 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. OH protocols are available in the VHA Clinical Occupational Health Guidebook on the CEOSH Web site at: http://vaww.ceosh.med.va.gov/01hp/pages/guidebooks.shtml.

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. The 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 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 BSL-3, 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 online at: http://www1.va.gov/ORO/Research_Compliance_Education.asp.

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 (RPSS), available online at: http://www.va.gov/vaforms/medical/pdf/10-0398.pdf, 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 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, have appropriate scopes of practice, and are 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 facility Safety staff 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 Safety Office interfaces with regulatory enforcement agencies during announced and unannounced inspections. The Safety Office coordinates medical surveillance with OH and ensures assessment of hazardous materials, environmental stressors (chemical, biological and physical), life safety, environmental compliance, and emergency management concerns within research areas.

The 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 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 Safety Office. The GEMS Coordinator may be a member of the Safety Office staff and is often responsible for hazardous waste management. GEMS Coordinators typically oversee management and disposal of waste streams and providing solutions to waste issues in research laboratories. The Radiation Safety Officer (RSO) may or may not be assigned to the 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) online at: http://www.cfm.va.gov/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, available online at:
http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2463. Items requiring reporting include:

- 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.
- Serious unanticipated problems involving risks to workers or the environment.
- 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 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, available online at:
http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2463.

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 percent 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): http://www1.va.gov/VASAFETY/AugStuff/VHADirective.pdf.
3. VHA Handbook 7701.01, Occupational Safety and Health (OSH) Program Procedures: http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2282.
4. VHA Handbook 1058.01, Research Compliance Reporting Requirements: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2463.
5. VHA Handbook 1200.01, The Research and Development (R&D) Committee: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2038.
6. VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1336.
7. VHA Handbook 1200.08, Safety of Personnel Engaged in Research: http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850.

1.12. Enclosures and Fact Sheets

Enclosure 1 Fact Sheet Listing

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

2. 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, available online at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml. A series of reference materials for many of the topics in this chapter are also available online from the American Industrial Hygiene Association (AIHA): http://www.aiha.org.

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: http://www.osha.gov/Publications/osha3071.pdf.
- Department of Energy (DOE) JHA Help Center: http://www.lbl.gov/ehs/jha/jha_tutorials.shtml.

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 2-5 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 Web site (http://www.osha.gov/SLTC/dermalexposure/index.html) and the NIOSH Skin Exposures & Effects Web site (http://www.cdc.gov/niosh/topics/skin/). See Enclosure 6 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 7.

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 8.

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 Industrial Hygiene Guidebook, available online at:
http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

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: http://www.cdc.gov/niosh/docs/77-173/.

4. OSHA Technical Manual, Personal Sampling for Air Contaminants: http://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_1.html#sae.

2.8. Enclosures

Enclosure 2	Sample Job Hazard Analysis: Handling, Transporting, and Storing Cryogens
Enclosure 3	Sample Job Hazard Analysis: Use and Maintenance of Electrical Laboratory Equipment
Enclosure 4	Sample Job Hazard Analysis: Preparing Samples for Analysis
Enclosure 5	Sample Gel Electrophoresis Job Hazard Analysis
Enclosure 6	Dermal Exposure Risk Assessment
Enclosure 7	Developing a Control Banding Model
Enclosure 8	Similarly Exposed Groups (SEGs)

EOSH

3. Hazard Communication

3.1. Introduction

Code of Federal Regulations (CFR) 29 CFR 1910.1200, Hazard Communication (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099) 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 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 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106) requirement for manufacturer's labels on incoming chemicals to not be removed or defaced remains unchanged. 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. This

system reclassifies health and physical hazards and requires a more formalized material safety data sheet (MSDS) structure, which are now called SDSs. 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 Engineering & Occupational Safety and Health (CEOSH) Web site (http://vaww.ceosh.med.va.gov/) under the Safety Management Program.

The revised HCS benefits employees by reducing confusion in the workplace, facilitating safety training, and improving understanding of chemical hazards. The revision of the HCS was a result of an international move, referred to as the United Nations' GHS (UN GHS), to standardize chemical information hazard awareness, labeling, and SDSs. The HCS revision 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. This guidebook chapter will discuss current and anticipated requirements as the sections of the standard are implemented. References to HCS will apply to both revised and original versions of the standard as VHA transitions to the revised standard. MSDSs and the new SDSs will be referred to as SDSs since all MSDSs will need to meet the new requirements.

3.2.1. Timeframe for HCS Implementation

1. By December 1, 2013, employers must train employees (and document completion) regarding the new label elements and SDS format.
2. By June 1, 2015, chemical manufacturer, importer, distributor, and employer provisions of the standard must be in place, which includes new SDS format. The following extensions have been approved by OSHA:
    - After December 1, 2015, any chemicals that are shipped from a Department of Veterans Affairs (VA) facility must comply with the new labeling requirements.
    - By June 1, 2016, local labeling system and the HCP at each facility must be compliant with the revised standards, and all employees must be trained on these changes.
3. Chemical manufacturers, importers, distributors, and employers may comply with either the original HCS (October 1, 2011 edition) or the revised HCS (including GHS), or both, during the transition period.

3.3. Summary of Changes to the Original HCS

The purpose, scope, and application of the HCS have not changed. The Hazard Communication Final Rule applies only to the HCS; therefore, the 29 CFR 1910.1450 is not affected. Research laboratory personnel must comply with specific aspects of the revised HCS that may affect implementation of the Research CHP.

The HCS modifications include:

- Revised criteria for classification of chemical health and physical hazards related to certain chemicals.
- A specific format for SDSs.
- Revised labeling provisions governing requirements for the use of standardized signal words, pictograms, hazard statements, and precautionary statements.
- Employee training on new requirements for labels and SDSs.

If a research laboratory develops a new compound, they are required to complete a hazard assessment and create an SDS. The revised HCS contains extensive information on mixture classification. However, this should apply only if a VHA investigator is developing a mixture for off-site distribution. Contact the Safety Office for guidance.

If hazardous chemicals are shipped from VHA laboratories, labeling requirements and Department of Transportation (DOT) and/or Federal Aviation Administration (FAA) regulations must be followed. Anyone involved in the packaging or shipping of hazardous materials must receive appropriate training.

Many parts of the original HCS will remain unchanged. The HCS still requires research laboratories to ensure that chemical labels are not removed or defaced. SDSs must be readily accessible during each work shift to research laboratory staff when they are in their work areas.

3.4. The Revised 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 online at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

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.

The following definitions are *added* to the revised HCS:

- Classification
- Hazard category
- Hazard class
- Hazard statement
- Label elements
- Pictogram
- Precautionary statement
- Product identifier
- Safety data sheet
- Signal word
- Substance
- Unclassified hazard

The following definitions are *removed* for the revised HCS:

- Combustible liquid
- Explosive
- Flashpoint
- Identity
- Organic peroxide
- Pyrophoric
- Water-reactive
- Compressed gas
- Flammable
- Hazard warning
- Material safety data sheet
- Oxidizer
- Unstable (reactive)

Definitions of the following are *updated* and can be found in the appendices of the revised HCS:

- Chemical
- Hazardous chemical
- Label
- Physical hazard
- Chemical name
- Health hazard
- Mixture

3.4.1. Written HCP

The requirement for a written HCP is unchanged. Depending on how each VHA site-specific HCP is written, only minor changes to definitions, hazard classification, and SDSs may be needed. All training materials should be augmented to reflect the revised HCS modifications. Labeling, SDSs, and training are discussed in detail in Section 3.6, Warning Signs and Labels; Section 3.7, MSDS to SDS; and Section 3.8, Training.

3.4.2. Trade Secrets

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. The revised HCS (i)(2) 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 revised HCS contains the accepted definition of trade secret and is accessible online at: http://www.osha.gov/dsg/hazcom/appendix_e.pdf.

3.5. Criteria for Classification of Chemical Hazards

The revised 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. An additional difference between the original HCS and the revised HCS is the evaluation of mixtures being shipped off-site. Detailed information on revised HCS guidelines for mixture classification is available online at: http://www.osha.gov/dsg/hazcom/global.html.

3.5.1. Health Hazards

The revised 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 revised HCS, available online at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10100.

The revised 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.

3.5.1.a. Acute Toxicity

The terms *toxic* and *highly toxic* are replaced with the term *acute toxicity* in the revised HCS. 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 revised HCS also provides category guidance for oral, dermal, and inhalation exposure. OSHA letter of interpretation number 20048 provides the relationship of health hazard definitions in the original HCS and the application to the OSHA Laboratory Standard: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20048.

3.5.1.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, and the original HCS specified the species and weight of the animal. The revised 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 revised HCS, available online at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099.

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

3.5.1.c. Serious Eye Damage or Eye Irritation

In the original HCS eye hazards are listed under target organs, and a chemical is identified as an eye irritant by using the specific procedure listed in 16 CFR 1500.42, Test for Eye Irritants (http://www.gpo.gov/fdsys/pkg/CFR-2012-title16-vol2/pdf/CFR-2012-title16-vol2-sec1500-42.pdf) or other appropriate techniques.

The revised HCS has two categories of eye hazards: Category 1 is Irreversible eye effects. *Serious eye damage* is defined in the revised 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.

3.5.1.d. Respiratory or Skin Sensitization

The original HCS defines a *sensitizer* as a chemical that causes allergic reaction in normal tissue after repeated exposure. The revised 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 revised HCS, available online at: http://www.osha.gov/dsg/hazcom/appendix_a.pdf.

3.5.1.e. Germ Cell Mutagenicity

The original HCS does not use the term *germ-cell mutagen*. The revised 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 revised 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 revised 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 revised HCS uses two categories of mutagenicity with subcategories including:

- Category 1, as defined in Appendix A of the revised 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 revised HCS: "Substances which cause concern for humans owing to the possibility that they may induce heritable mutations in the germ cells of humans."

3.5.1.f. Carcinogenicity

A carcinogen is defined as a substance that induces or increases the incidence of cancer. According to Appendix A of the revised 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 revised 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).

3.5.1.g. Reproductive Toxicity

The original HCS identified reproductive toxins by their effect on target organs; the revised 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 revised 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.

3.5.1.h. Specific Target Organ Toxicity (Single or Repeated Exposure)

The original HCS did not differentiate between a single exposure [specific target organ toxicity-single exposure (STOT-SE)] and repeated or prolonged exposure [specific target organ toxicity-repeated exposure (STOT-RE)].

STOT-SE

In the revised 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.

3.5.1.i. Aspiration Hazard

Aspiration is a new hazard not found in the original HCS. An *aspiration hazard* is defined in the revised 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.

3.5.2. Physical Hazards

The original HCS identified nine physical hazards:

- Combustible liquid
- Explosive
- Organic peroxide
- Pyrophoric
- Water reactive
- Compressed gas
- Flammable
- Oxidizer
- Unstable (reactive)

Typically, safety hazards related to the physical characteristics of a chemical can be defined objectively in terms of testing requirements.

The revised 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 revised HCS Physical Hazards is found in the revised HCS Appendix B, Physical Criteria (Mandatory), online at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099.

3.5.2.a. Explosives

As stated in Appendix B of the revised 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

(http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9755) has clearly defined regulations. Trinitrotoluene and nitroglycerine are examples of an explosive.

3.5.2.b. Flammable Gases

The revised 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 revised 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.

3.5.2.c. Flammable Aerosols

According to the revised 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.

3.5.2.d. Flammable Solids

The revised 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 revised HCS (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10101).

3.5.2.e. Oxidizing Gases

Oxidizer was previously defined as a chemical that initiates or promotes combustion in other materials. The revised HCS now 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.

3.5.2.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.

3.5.2.g. Oxidizing Solids

An oxidizing solid is defined in the revised 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.

3.5.2.h. Gases Under Pressure

The original HCS used the term *compressed gas*, while the revised 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.

3.5.2.i. Flammable Liquids

The original HCS defined *flammable liquids* as having a flash point less than 38.7ºC (100ºF) and combustible liquids with a flash point less than 93.3°C (200°F). Under the revised HCS, the term *combustible liquid* has been eliminated and those liquids have been incorporated into the flammable liquid class. A flammable liquid is now defined as having a flash point of not more than 93°C (199.4°F). The methods for testing flash point have been changed. According to the revised 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

3.5.2.j. Self-Reactive Chemicals

The original HCS used the term *unstable* (reactive) to mean a chemical that will vigorously polymerize, decompose, condense, or become self-reactive under conditions of shock. The revised HCS does not use the term unstable and refers to this class of chemicals as *self-reactive* 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 revised 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 revised HCS (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10101). Ammonium perchlorate is an example of a self-reactive chemical.

3.5.2.k. Pyrophoric Liquids

The revised HCS divides pyrophorics in two classes (liquid and solid), and defines different test criteria. The original HCS used only the term *pyrophoric* and did not differentiate between states of matter. The historical criteria for pyrophoric material is that it will ignite spontaneously in air at a temperature of 54.4ºC (130ºF) or lower.

In the revised 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 (http://www.unece.org/trans/danger/publi/manual/rev4/manrev4-files_e.html). 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.

3.5.2.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.

3.5.2.m. Self-Heating Chemicals

Self-heating chemicals is a new class in the revised 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.

3.5.2.n. Chemicals, Which, in Contact With Water, Emit Flammable Gases

The original HCS uses the term *water reactive* to identify a chemical that reacts with water and releases a gas that is either flammable or a health hazard. The revised HCS replaces water reactive with *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 revised 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.

3.5.2.o. Organic Peroxides

The original and revised HCS use the same definition for *organic peroxides*. However, the revised HCS specifies a test method and addresses mixtures.

According to Appendix B of the HCS (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10101):

> 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.

3.5.2.p. Corrosive to Metals

The original HCS does not use the term *corrosive to metals* and indicates that the term *corrosive* does not refer to action on inanimate surfaces. In the revised 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.

3.6. Warning Signs and Labels

The revised HCS labeling requirements are significantly different from those in the original HCS. The original standard was performance-oriented and allowed chemical manufacturers to choose language to convey hazards. In the revised 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 revised HCS indicates the specific information to be provided for each hazard class and category once a chemical is classified (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10102).

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

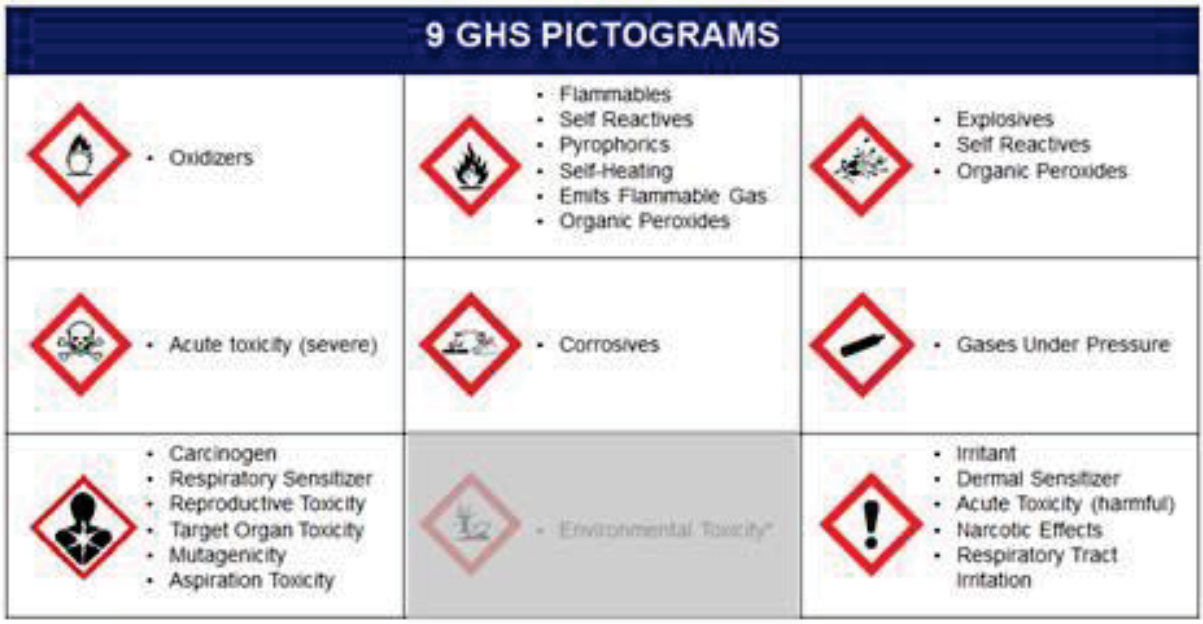
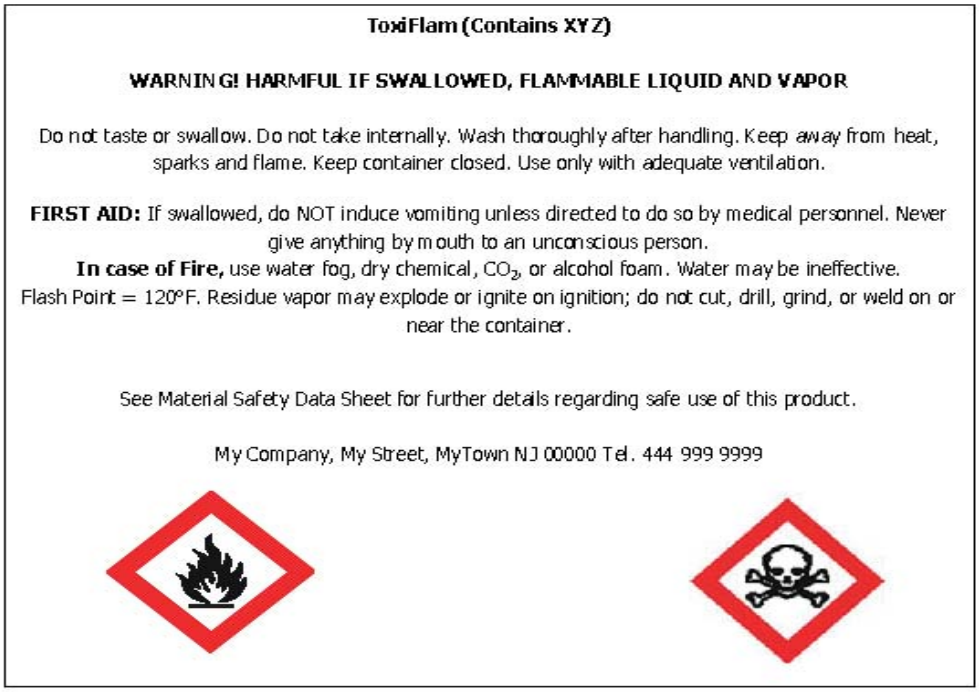


Figure 3-2: Acceptable Pictograms and Hazard Classes for the Revised HCS (Source: OSHA, 2009: http://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf)

3.6.1. Labeling Example

Figure 3-3 is an example of a label based on the revised 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).



ToxiFlam (Contains XYZ)

WARNING! HARMFUL IF SWALLOWED, FLAMMABLE LIQUID AND VAPOR

Do not taste or swallow. Do not take internally. Wash thoroughly after handling. Keep away from heat, sparks and flame. Keep container closed. Use only with adequate ventilation.

FIRST AID: If swallowed, do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person.
In case of Fire, use water fog, dry chemical, CO_2, or alcohol foam. Water may be ineffective.
Flash Point = 120°F. Residue vapor may explode or ignite on ignition; do not cut, drill, grind, or weld on or near the container.

See Material Safety Data Sheet for further details regarding safe use of this product.

My Company, My Street, MyTown NJ 00000 Tel. 444 999 9999

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: http://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf)

3.6.2. 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).

3.7. MSDS to SDS

The original HCS and revised HCS require similar information on an MSDS. However, the original HCS allowed any format to be used. The UN GHS refers to MSDSs as SDSs, and standardizes the section headings, content, and order of information. Signal word (*Warning* or *Danger*), hazard statements, symbols, and precautionary statements consistent with the UN GHS classification are required on the SDS.

The revised HCS includes Appendix D: Safety Data Sheets (Mandatory) (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10103), 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 revised HCS allows electronic copies of the SDS, a VA Union Master Agreement requires one hard copy to be maintained at the facility.

3.8. Training

For the research laboratory, employee information and training is an important element of any safety program. The revised 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 revised 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 revised 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 revised labeling system and the local system that is used to label secondary containers in the research laboratory, as outlined in the Research CHP.

3.9. References and Resources

1. 16 CFR 1500.42, Test for Eye Irritants: http://www.gpo.gov/fdsys/pkg/CFR-2012-title16-vol2/pdf/CFR-2012-title16-vol2-sec1500-42.pdf.
2. 29 CFR 1910.109, Explosives and Blasting Agents: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9755.
3. 29 CFR 1910.1200, Hazard Communication: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099.
4. ANSI Z129.1, Hazardous Workplace Chemicals - Hazard Evaluation and Safety Data Sheet and Precautionary Labeling Preparation: http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+Z400.1%2FZ129.1-2010.
5. ISO 10156:1996, Gases and Gas Mixtures--Determination of Fire Potential and Oxidizing Ability for the Selection of Cylinder Valve Outlets: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=25585.
6. OSHA (2012). A Guide to the Globally Harmonized System of Classification and Labeling of Chemicals (GHS): http://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf.
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: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

3.10. Enclosures and Fact Sheets

Enclosure 1 Fact Sheet Listing

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

3.1 Hazard Communication for Research Laboratories

4. 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 safety data sheets (SDS) and chemicals. The Research CHP is mandated by Code of Federal Regulations (CFR) 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories, which can be viewed online at:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106.

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 inthe 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 (http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850) outlines the management protocol for research laboratory chemicals.

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 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 to include 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, who should be a member of the SRS.
- Written standard operating procedures 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 a device 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 standard operating procedures (SOPs) and security for storage and handling. Research laboratory staff should refer to VHA Directive 1200.06, Control of Hazardous Agents in VA Research Laboratories, available online at: http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1336.

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, available online at: http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850. A sample Research CHP is provided in Enclosure 9. *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 as required by 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 (http://www.osha.gov/Publications/laboratory/OSHAquickfacts-lab-safety-labeling-chemical-transfer.pdf) 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 CEOSH Web site at: http://vaww.ceosh.med.va.gov/. 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 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9752) 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 are 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 CEOSH Web site at: http://vaww.ceosh.med.va.gov/. 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 byproduct(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 (http://www.uscg.mil/hq/nsfweb/foscr/ASTFOSCRSeminar/References/CHRISManualIntro.pdf).
- Cole Palmer Chemical Compatibility Database (http://www.coleparmer.com/Chemical-Resistance).
- Vanderbilt University Chemical Compatibility Chart (http://www.safety.vanderbilt.edu/chem/chem-compatability-chart.php).
- Mallinckrodt Specialty Chemicals Co. – Chemical Compatibility List (http://web.princeton.edu/sites/ehs/chemwaste/MallinckrodtChemicalCompatibilityList.pdf).

Other supplier sites and university 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 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9765), 29 CFR 1910.1200, Hazard Communication (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099), and 29 CFR 1910.1450 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106). 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)/Research Chemical Hygiene Officer (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 VA 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 does not require an SDS to be 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), online at: http://www.phmsa.dot.gov/hazmat/regs. 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 available online at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title49-vol2/pdf/CFR-2010-title49-vol2-sec171-1.pdf.

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 Web site online at: https://www.iata.org/whatwedo/cargo/dgr/pages/infectious_substances.aspx. 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 Clinical Occupational Health Guidebook, available on the CEOSH Web site at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml, 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: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9752.

2. 29 CFR 1910.1450, Occupational Exposure to Hazardous Chemicals in Laboratories: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106.

3. 49 CFR 171.1, Applicability of Hazardous Materials Regulations (HMR) to Persons and Functions: http://www.gpo.gov/fdsys/pkg/CFR-2010-title49-vol2/pdf/CFR-2010-title49-vol2-sec171-1.pdf.

4. Centers for Disease Control and Prevention (CDC) Agency for Toxic Substances & Disease Registry (ATSDR), Division of Toxicology and Environmental Medicine: http://www.atsdr.cdc.gov/dtem/index.html.

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

6. Lawrence Berkeley National Laboratory, Safety Division, Chemical Hygiene Plan: http://www.lbl.gov/ehs/chsp/html/chsp_site_map.shtml.

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

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

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

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

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

12. OSHA Letter of Interpretation: Laboratory Standard (#20048): http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20048.

13. VHA Directive 1200, Veterans Health Administration Research and Development Program: http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2043.

14. VHA Handbook 1200.06, Control of Hazardous Agents in VA Research Laboratories: http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1336.

15. VHA Handbook 1200.08, Safety of Personnel Engaged in Research: http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850.

4.8. Enclosure

Enclosure 9 Sample Research Chemical Hygiene Plan

EOSH

5. 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.

5.2. Chemical Hazards

All chemicals have the potential to be hazardous due to toxicity and/or dangerous physical properties. 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 (gloveboxes) 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.

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 (http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1850), Section 7.d.

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.

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:

- 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 dollie 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 General Safety Guidebook, available online at:
http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

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 lower oxygen concentrations. 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. 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 immediately dangerous to life or health (IDLH) asphyxiant atmosphere.
- 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.

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 result in immediate heat or pain but may leave the skin feeling slick or soapy and may result in significant tissue damage.

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.
- Transport all corrosives in a bottle carrier with built-in secondary containment that will contain 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 2009-026, Location, Selection, Installation, Maintenance, and Testing of Emergency Eyewash and Shower Equipment, available online at: http://vaww1.va.gov/vhapublications/ViewPublication.asp?pub_ID=2023.
- 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.

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.	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.

Text description of this table is available on a separate page.

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 Bases	Chemical Examples	Storage Guidelines
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.

Text description of this table is available on a separate page.

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 Code of Federal Regulations (CFR) 29 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
K_2CrO_7: Potassium dichromate	$Na_2S_2O_8$: Sodium persulfate
KIO_3: Potassium iodate	

Text description of this table is available on a separate page.

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; and picric acid. 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 Web site at:
http://www.lbl.gov/ehs/chsp/html/react_peroxides.shtml.

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.

Some lessons learned on peroxide-forming chemicals, are discussed on the University of California, Berkeley Web site at: http://www.ehs.berkeley.edu/hs/129-lessons-learned-at-uc-berkeley/343.html.

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.

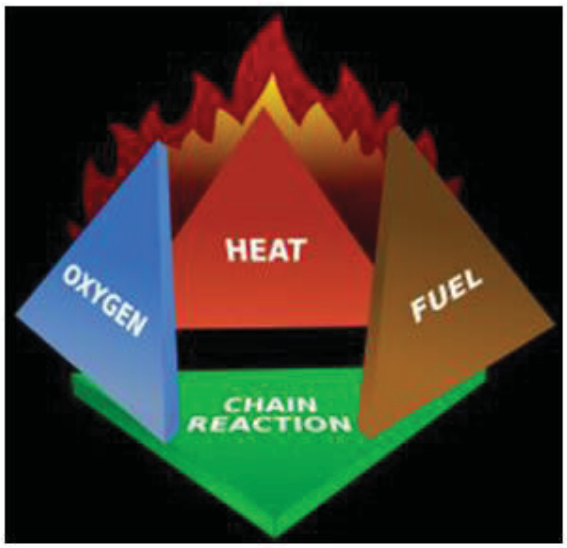


Figure 5-1: Fire Tetrahedron (Source: Gravity and Momentum, 2011: http://www.gravityandmomentum.org/2011/04/fuego/)

5.5.7.a. Flammable Solids

Flammable solids are defined as desensitized explosives or, as stated in 49 CFR 173.124, Hazardous Materials, “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 available online at: http://vaww.ceosh.med.va.gov/guidebooks.shtml.

5.5.7.b. Flammable Liquids

Flammable liquid means a liquid with a flash point of 93°C (199.4°F) or less. A recent change to the Hazard Communication Standard that incorporated the United Nations Globally Harmonized System (GHS) of Classification and Labeling of Chemicals definitions combined flammable and combustible liquids into one hazard class, "Flammable Liquids". 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 (current version) (http://www.cdc.gov/niosh/docs/2005-149/pdfs/2005-149.pdf).

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

Text description of this table is available on a separate page.

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 (http://www.osha.gov/dsg/hazcom/hazcom-appendix-b.html)

Text description of this table is available on a separate page.

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 (°F). 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)] and 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 percent of a test animal population. For airborne exposures, lethality is expressed as a lethal concentration 50 percent (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, exposure to many organic solvents in low dose over a long period of time 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 10, 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, available online at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9991. 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®). VHA employees can access the TLVs® online at: http://vaww.ceosh.med.va.gov/01IH/Pages/ThresholdLimitvaluesBiologicalExposureIndicies.shtml. TLVs® can also be purchased directly from ACGIH® online at: http://www.acgih.org/tlv/. 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.

Text description of this table is available on a separate page.

Additional information on TWA, STEL, and ceiling limits can be found in the Industrial Hygiene Guidebook available on the CEOSH Web site at: http://vaww.ceosh.med.va.gov/01HP/Pages/guidebooks.shtml.

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, available online at: http://www.cdc.gov/niosh/npg/.

5.7. References and Resources

1. Centers for Disease Control and Prevention (CDC) Agency for Toxic Substances & Disease Registry (ATSDR), Division of Toxicology and Environmental Medicine: http://www.atsdr.cdc.gov/dtem/index.html.

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 Plan: http://www.lbl.gov/ehs/chsp/html/chsp_site_map.shtml.

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: http://www.nlm.nih.gov/pubs/factsheets/toxnetfs.html.

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

9. OSHA Letter of Interpretation: Laboratory Standard (#20048): http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=20048.

5.8. Enclosures and Fact Sheets

Enclosure 1 Fact Sheet Listing

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 10 Additional Toxicology Information

EOSH

6. 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, online at: http://www.cdc.gov/biosafety/publications/bmbl5/.

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), available online at: http://www.cfm.va.gov/til/dManual/dmMEhosp.pdf. There is also a design guide for specific facility types available in the TIL (http://www.cfm.va.gov/til/dGuide.asp).

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 (http://www.cfm.va.gov/til/dGuide.asp), 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 11. Detailed information on research laboratory exhaust ventilation is provided in Enclosure 12.

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.

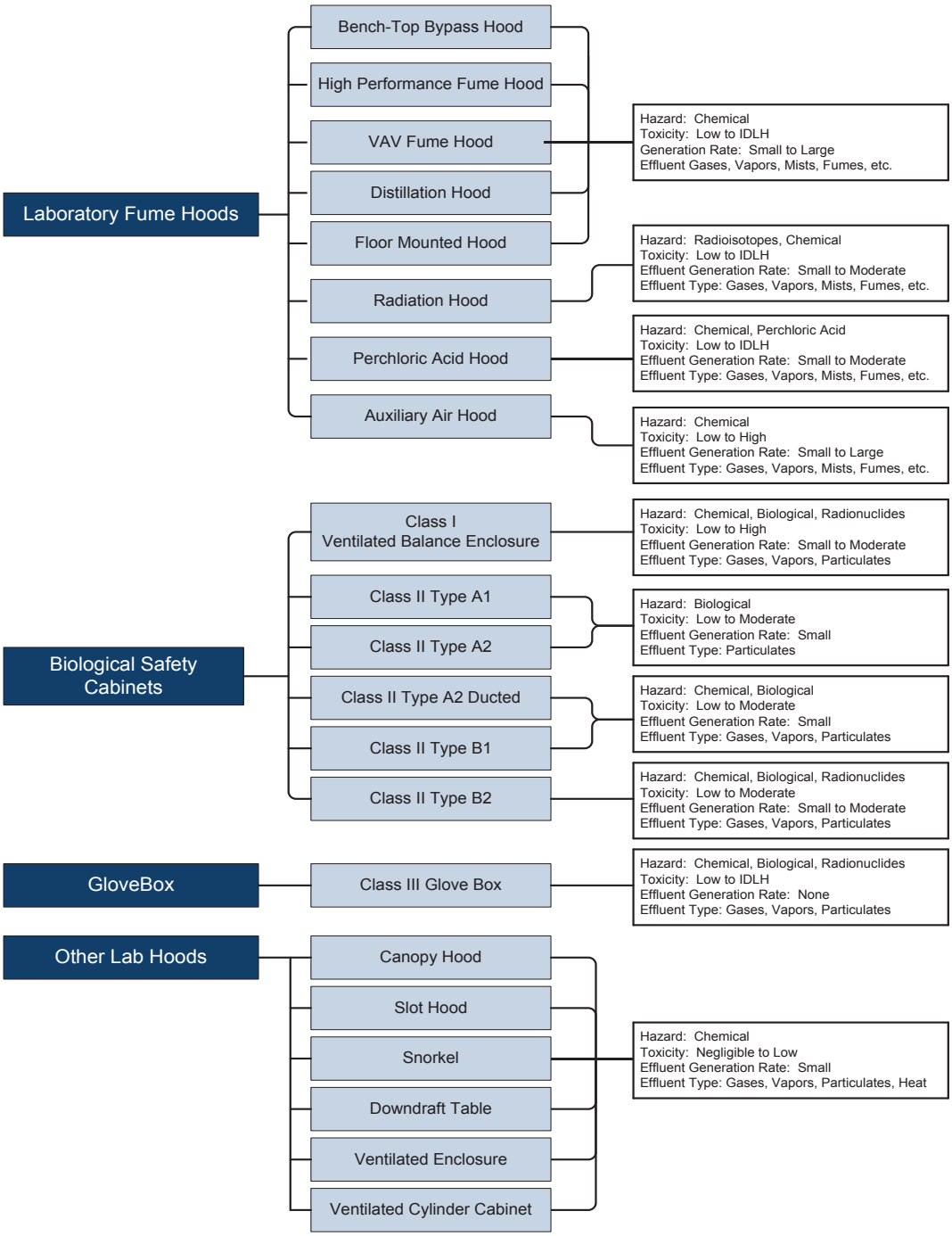


Figure 6-1: Different Containment Devices and Potential Applications
(Source: Exposure Control Technologies Inc., 2011)

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.

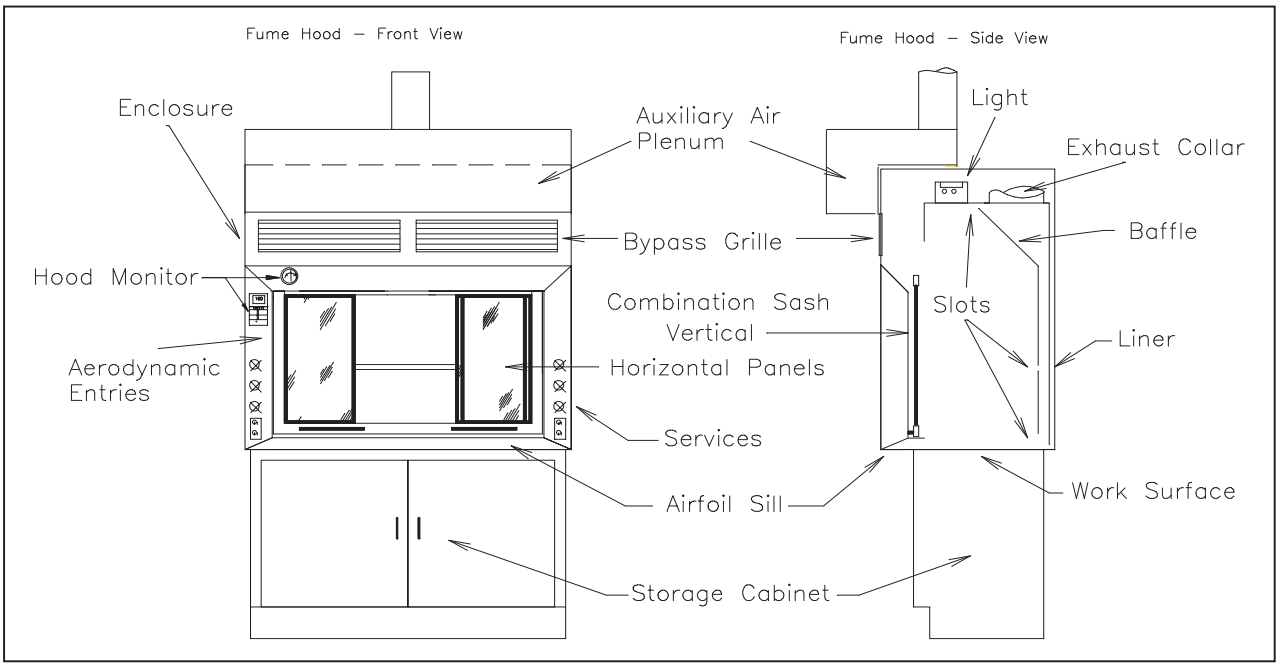


Figure 6-2: Fume Hood Components (Source: ASHRAE 110, Method of Testing Performance of Laboratory Fume Hoods)

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

(http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10100) 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 13.

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.

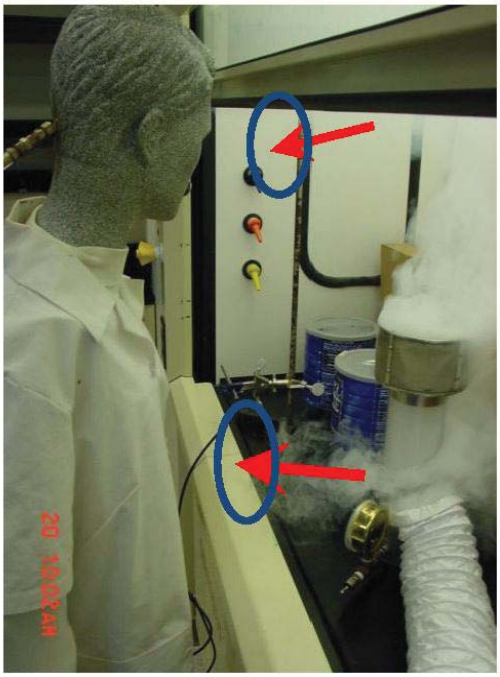


Figure 6-3: Areas Prone to Escape in a Fume Hood
(Source: Exposure Control Technologies Inc., 2011)

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.

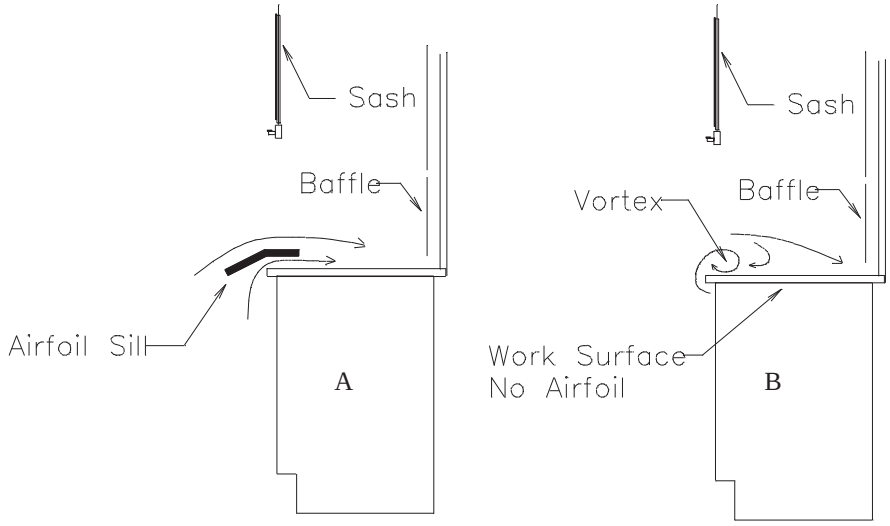


Figure 6-6: Fume Hood Work Surface Diagram Showing Air Flow Patterns With and without Airfoil Sill
(Source: Exposure Control Technologies Inc., 2011)

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.

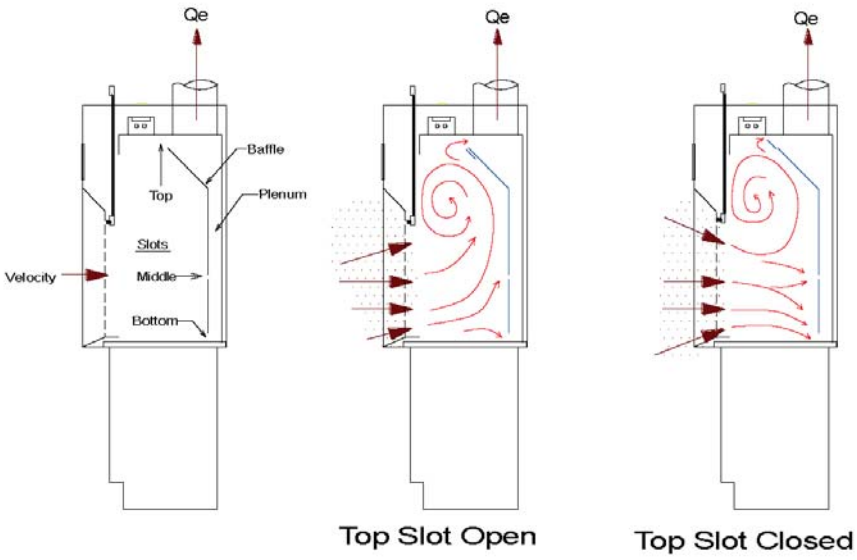


Figure 6-7: Design and Configuration of Baffle Panels and Capture Slots
(Source: Exposure Control Technologies Inc., 2011)

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 percent or greater than 120 percent 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 6-11) 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 percent. The accuracy of the monitor must be plus or minus 5 percent of the measured value, and the calibration of the monitor should be verified on an annual basis.

Figure 6-11: 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) Web site at: http://www.afm.ars.usda.gov/shem/files/s&e-283p2.pdf.

Enclosure 14 includes recommended tests applicable to different fume hood types. Enclosure 15 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 6-12.

Figure 6-12: 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

1. ACGIH® (1992). Industrial ventilation: A manual of recommended practice. (21st ed.) Cincinnati, OH.

2. ACGIH® (2002). Threshold Limit Values (TLVs®) for chemical substances and physical agents. Cincinnati, OH.

3. ACGIH® (2010). Industrial ventilation: A manual of recommended practice for design. (27th ed.) Cincinnati, OH.

4. American Glovebox Society (1998). Guideline for gloveboxes AGS-1998-001. (2nd ed.) Santa Rosa, CA.

5. ANSI/ASHRAE 41.7-1984, Method of Test Measurement of Flow of Gas (RA 2000).

6. ANSI/ASHRAE 41.2-1987, Standard Methods for Laboratory Air Flow Measurement. (RA 1992).

7. ANSI/ASHRAE 41.3-1989, Standard Method for Pressure Measurement.

8. ANSI/ASHRAE 110-1995, Method of Testing Performance of Laboratory Fume Hoods.

9. ANSI/AIHA Z9.5, Laboratory Ventilation.

10. ASHRAE 62, Ventilation for Acceptable Indoor Air Quality.

11. ASHRAE 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings.

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15. Institute of Laboratory Animal Resources (1996). Guide for the care and use of laboratory animals. Washington, DC: National Academies Press.

16. Laboratories for the 21st Century (2008). Best Practice Guide Optimizing Laboratory Ventilation Rates.

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

18. Prudent Practices in the Laboratory: Handling and Disposal of Chemicals. National Research Council.
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

Enclosure 1 Fact Sheet Listing

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

8.1 General Research Laboratory Ventilation and Fume Hoods

Enclosure 11 General Research Laboratory Design Specifications

Enclosure 12 Research Laboratory Exhaust Ventilation

Enclosure 13 Additional Fume Hood Types and Information

Enclosure 14 Recommended Tests for Different Fume Hood Types

Enclosure 15 Research Laboratory Fume Hoods and Hazards Information

EOSH

Enclosures

Enclosures can only be printed by accessing links online.

Enclosure 1 Fact Sheet Listing

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

Enclosure 3 Sample Job Hazard Analysis: Use and Maintenance of Electrical Laboratory Equipment

Enclosure 4 Sample Job Hazard Analysis: Preparing Samples for Analysis

Enclosure 5 Sample Gel Electrophoresis Job Hazard Analysis

Enclosure 6 Dermal Exposure Risk Assessment

Enclosure 7 Developing a Control Banding Model

Enclosure 8 Similarly Exposed Groups (SEGs)

Enclosure 9 Sample Research Chemical Hygiene Plan

Enclosure 10 Additional Toxicology Information

Enclosure 11 General Research Laboratory Design Specifications

Enclosure 12 Research Laboratory Exhaust Ventilation

Enclosure 13 Additional Fume Hood Types and Information

Enclosure 14 Recommended Tests for Different Fume Hood Types

Enclosure 15 Research Laboratory Fume Hoods and Hazards Information