

UNIVERSITY OF CALIFORNIA

ENVIRONMENT, HEALTH & SAFETY
(EH&S)

LABORATORY SAFETY DESIGN
GUIDE

Second Edition
September 2007

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INTRODUCTION

First Edition, July 2002

The University of California system has a continuing need to modernize and upgrade its facilities. The resulting construction projects often have significant health and safety requirements due to regulatory oversight. In addition, good practices followed in the design phases of a project can reduce the cost of ownership and difficulties encountered by users of a facility during the facility's life cycle. Since these requirements and concerns impact the design of a project, the University of California Industrial Hygiene Program Management Group has prepared the *University of California EH&S Laboratory Safety Design Guide* to aid the campus communities during the planning and design phases of a project.

The *Design Guide* is a resource document for use by design professionals, faculty, and staff for use during the planning and early design phases of a project. The University of California Industrial Hygiene Program Management Group believes that the *Design Guide*, in conjunction with environmental and occupational safety and health ("EH&S") plan review and consultation, will improve design efficiency and minimize changes.

The requirements of the *Design Guide* apply to all laboratory buildings, laboratory units, and laboratory work areas in which hazardous materials are used, handled, or stored. It also addresses biological safety and ionizing and nonionizing radiation situations commonly found in laboratories. The University of California Industrial Hygiene Program Management Group believes this standard represents the minimum requirement; more stringent requirements may be necessary, depending on the specific laboratory function or contaminants generated. However, variances may be individually allowed for specific remodeling projects when approved by the campus EH&S organization(s) on a case-by-case basis.

The word "shall" is used consistently wherever the UC Industrial Hygiene Program Management Group believes actions are required, not just where statutory requirements compel action. The word "must" has been avoided. Campuses are free to amend this guide to identify which specifications are mandated by regulatory codes and statutory requirements, and to otherwise tailor this document to fit their needs. Tailoring, however, should not mean ignoring or deleting sections of this document that apply to situations at a campus.

Each specification is broken into two (occasionally three) parts. The first part is the specification; the second part is the source of the specification; and the third part is explanatory text. Definitions are found in Appendix A, while the standards that underpin the *Design Guide* are specified in Appendix B at the end of the document.

The *Design Guide* is not "all inclusive." It covers neither all regulatory issues nor all design situations. In all cases, the campus EH&S organization(s) should be consulted on questions regarding health, safety, and environment.

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In addition, the University of California Fire Marshals Group reviewed this document. Their contributions were significant and valuable.

It has been good to work with such competent and qualified people.

It is acknowledged that there will be errors in a document as complex as this one. Please direct comments or questions to my attention at: miller22@llnl.gov. Please direct technical questions to your local ES&H organization.

Gordon Miller, Editor
Livermore, California
July 23, 2002

Second Edition, September 2007

This second edition reflects an evolutionary review of the first edition. All chapters were reviewed, and content and references were updated. Two additional chapters were added: Chapter 2 (Electrical) and Chapter 11 (Ergonomics Design and Laboratory Spaces). Reviewers of the chapters were as follows:

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A. Scope

The primary objective in laboratory design should be to provide a safe, accessible environment for laboratory personnel to conduct their work. A secondary objective is to allow for the maximum flexibility for safe research use. Undergraduate teaching laboratories require other specific design considerations. Therefore, health and safety hazards shall be anticipated and carefully evaluated so that protective measures can be incorporated into the design wherever possible. However, no matter how well designed a laboratory is, improper use of its facilities will always defeat the engineered safety features. Proper education of the facility users is essential.

The General Requirements listed below illustrate some of the basic health and safety design features required for new and remodeled laboratories. Variations from these guidelines need approval from the campus environment, health, and safety (EH&S), fire protection, and radiation protection organizations.

B. Building Requirements

1. Designer Qualifications — The designer shall have the appropriate professional license in his/her area of expertise.
Good Practice
2. Building Occupancy Classification — Occupancy classification is to be based upon an assessment of a projected chemical inventory of the building. Prior to the final design, the campus fire safety organization will need to assign an occupancy class to insure compliance with the building codes.
24 CCR, Part 2
24 CCR, Part 9
3. Environmental Permits — Project managers shall consult with the campus Environmental Protection Office to identify permitting and pollution abatement engineering requirements for the building. This should be done well before key resource allocation decisions are made.

C. Building Design Issues

Note:

Because the handling and storage of hazardous materials inherently carries a higher risk of exposure and injury, it is important to segregate laboratory and nonlaboratory activities. In an academic setting, the potential for students to need access to laboratory personnel, such as instructors and assistants, is great. A greater degree of safety will result when nonlaboratory work and interaction is conducted in a space separated from the laboratory.

1. Provide separate office spaces for laboratory employees.

Prudent Practices in the Laboratory

Good Practice

It is prohibited to store or consume food, apply makeup, handle contact lenses, or chew gum in areas where hazardous materials are used and/or stored.

2. Public access to laboratory personnel in office rooms with separate corridor access is highly desirable.

Prudent Practices in the Laboratory

3. An automatically triggered main gas shutoff valve for the building shall be provided for use in a seismic event. In addition, interior manual shutoff valves shall be provided for both research and teaching areas.

Good Practice

4. Large sections of glass shall be shatter-resistant.

Good Practice

In the event of a severe earthquake, as the glass in cabinets and windows breaks, the shards need to be protected to prevent injury.

D. Laboratory Design Considerations

1. A process that integrates key decision makers (e.g., health and safety, users, facility operators) into the design team should be used.

2. The laboratory shall be completely separated from outside areas (i.e., shall be bound by four walls and a roof or ceiling).

17 CCR

State of California, Department of Health Services, Radiologic Health Branch, Guide for the Preparation of Applications for Medical Programs (RH 2010 4/90)

3. Design of the laboratory and adjacent support spaces shall incorporate adequate additional facilities for the purpose of storage and/or the consumption of food, drinks, tobacco products, and the application of cosmetics.

Prudent Practices in the Laboratory

17 CCR

Good Practice

State of California, Department of Health Services, Radiologic Health Branch, Guide for

1. General Requirements for Laboratories

the Preparation of Applications for Medical Programs (RH 2010 4/90)

4. Mechanical climate control should be provided as needed.

Good Practice

The lab shall be within normally acceptable thermal ranges prior to permanent occupancy. Electrical appliances often exhaust heat into a room (e.g., freezer, incubator, autoclave). Failure to take this effect into consideration may result in an artificially warm working environment. Windows shall not be opened for a cooling effect since the room air balance will be altered.

See Chapter 3 of this document for laboratory ventilation design issues.

5. Supply and exhaust systems shall meet the requirements of ANSI/ASHRAE 62 and ANSI/AIHA Z9.5.

Good Practice

See Chapter 3 of this document for laboratory ventilation design issues.

6. When office and lab spaces are connected, airflow should enter via office spaces, and exit via hoods or other exhausts in lab spaces.

Good Practice

7. Laboratories should be designed with adequate workstation space, e.g., computers for instruments or data entry.

Good Practice

8. Laboratory benches' standard depths are 30 inches for a wall bench, and 66 inches for an island bench. Bench lengths usually allow for 72 inches of free counter space per laboratory worker, in addition to the counter space allotted for equipment.

9. Deskwork areas in laboratories shall be separate from areas where hazardous materials are used. Specifically, fume-hood openings shall not be located opposite desk-type work areas.

NFPA 45 Chapter 6–9.3

10. Workstations in the laboratory need to accommodate computer monitors, keyboards, and work holders, and should have height adjustable work surfaces to minimize injuries from repetitive-motion stress.

Good Practice

The greatest potential ergonomic need is from poorly designed laboratory workstations. When designing a “knee hole,” place it upon a height-adjustable work surface with a space in the cabinet or shelf for a “monitor hole”.

11. Ensure that casework has no vibration/ movement or loading limitations, is not seismic sensitive, interacts with laboratory equipment, is ergonomically designed, and is responsive to ADA concerns.

Good Practice

12. Floor loading should be no more than 100–125 pounds/in². Heavy support

1. General Requirements for Laboratories

equipment should be located elsewhere.

Good Practice

13. Support columns should not be placed in open laboratory areas, but should be incorporated into lab benches, if possible.

Good Practice

14. Avoid wet sprinklers in ductwork; avoid nonfireproof material in interstitial spaces.

Good Practice

15. Locate eyewash/safety shower near door. Do not include a floor drain for the shower.

Good Practice

See Chapter 4 of this document for eyewash/safety shower issues.

16. Where hazardous, biohazardous, or radioactive materials are used, each laboratory shall contain a sink for hand washing. The sink drain shall be connected either to a retention tank or building plumbing.

NIH Biosafety in Microbiological and Biomedical Laboratories, BSL 2, D.1

NIH Guidelines for Research Involving Recombinant DNA Molecules, App. GII-B-4-d

17. All work surfaces (e.g., benchtops, counters, etc.) shall be impervious to the chemicals and materials used in the laboratory. The countertop should incorporate a lip to prevent run-off onto the floor.

California Department of Health Services, Radiologic Health Branch

NIH Biosafety in Microbiological and Biomedical Laboratories, BSL 2, D.3

NIH Guidelines for Research Involving Recombinant DNA Molecules, Appendix G-II-B-4-b

The lab bench shall be resistant to the chemical actions of chemicals and disinfectants. "Fiberglass" (glass fiber reinforced epoxy resin) is inappropriate because it can be degraded by some chemicals and can release toxic smoke when burned. Wooden benchtops are not appropriate.

18. The laboratory shall be designed so that it can be easily cleaned. Benchtops shall be a seamless one-piece design to prevent contamination. Laminate benchtops are not suitable. Penetrations for electrical, plumbing, and other considerations shall be completely and permanently sealed. If the bench abuts a wall, it shall be coved or have a backsplash against the wall. The countertop should incorporate a lip to prevent runoff onto the floor.

NIH Biosafety in Microbiological and Biomedical Laboratories, BSL 2, D.2

NIH Guidelines for Research Involving Recombinant DNA Molecules, App. GII-B-4-a

19. Laboratory flooring in chemical use areas and other high hazard areas (such as biological containment facilities) shall be chemically resistant and one piece, and with covings to the wall. This can be achieved by use of glue, or heat welded vinyl flooring. Floors in storage areas for corrosive liquids shall be of liquid-tight construction. Waxed and sealed vinyl floor tiles are suitable in low-hazard areas.

State of California, Department of Health Services, Radiologic Health Branch, Guide for the Preparation of Applications for Medical Programs (RH 2010 4/90)

24 CCR 9 (CFC) 8003.1.7.2, 8003.14.1.2

24 CCR 2 307.2.12

1. General Requirements for Laboratories

The floors shall be solid slab or seamless sheet vinyl. A continuous floor reduces the potential of liquid absorption. Covings are recommended to facilitate cleanup. Surfaces should be as free of cracks, crevices, seams, and rough surfaces as possible to avoid surface-contamination traps.

20. The walls will be nonporous and painted with a durable, impervious finish in such a manner to facilitate decontamination. High-gloss paint is recommended.

Good Practice

21. Ports should be provided for obtaining samples of effluent from building laboratory drains.

Good Practice

22. Vented cabinets with electrical receptacles and sound insulation should be provided for the placement of individual vacuum pumps, where their use is anticipated. A one- to two-inch hole for the vacuum line hose from the cabinet to the benchtop shall be provided.

Good Practice

23. Laboratory areas should be well lit to avoid spills and other accidents that could result in contamination buildup.

Good Practice

NUREG 1556, Vol. 7, Appendix L

Safe Handling of Radionuclides, Section 3.3.5 (1973 ed.)

State of California, Department of Health Services, Radiologic Health Branch RH 2010 4/90

E. Hazardous Materials Design Issues

1. Facilities shall be designed so that use of a respirator is not required for normal operations.

Good Practice

29 CFR 1910.134(a) (1)

NCRP Report No. 127 Section 4.5

2. Where appropriate, general ventilation systems should be designed, such that, in the event of an accident, they can be shut down and isolated to contain radioactivity or hazardous chemicals.

Good Practice

NUREG 1556, Vol. 7, Appendix L

3. A pressure differential system should be used to control the flow of airborne contamination. The flow should always be from clean areas to contaminated areas, but it shall be recognized that similar areas may not always require the same ventilation characteristics.

Good Practice

NCRP Report, No. 127, Section 4.5

4. An area for spill or emergency response equipment shall be located on each floor. This area shall be a minimum of 50 square feet (4.6 m²), with an increase in the size at the rate of 5 square feet (0.46 m²) per 1,000 square feet (93 m²) in excess

1. General Requirements for Laboratories

of 10,000 square feet (929 m²), and shall have at least two standard electrical outlets and overhead lighting.

*Prudent Practices in the Laboratory 5.C.11.5 & 5.C.11.6
24 CCR Part 2 307.2.12 (applies to H-8 occupancies)*

5. The laboratory shall have a means of securing specifically regulated materials such as controlled substances regulated by the Drug Enforcement Administration, select agents regulated by Center for Disease Control (CDC), and radioactive materials (i.e., lockable doors, lockable cabinets etc.), where applicable.

*17 CCR, California Radiation Control Regulations
Controlled Substances Act, Section 803
State of California, Department of Health Services, Radiologic Health Branch RH 2010 4/90*

6. Sufficient space or facilities should be provided, so that materials that have unique physical or hazardous properties are stored safely, and that materials that, in combination with other substances, may cause a fire or explosion, or may liberate a flammable or poisonous gas, are kept separate. Separate space or facilities can include storage cabinets with partitions, acid cabinets, flammable cabinets, gas cabinets, etc.

*24 CCR 9 (CFC) 8001.9.8
NFPA 45, Chapter 9.2*

When designing the shelves and shelf spacing, it is important to include enough space (height and depth) for secondary containers.

F. Entries, Exits, and Aisle Width

1. The main emergency egress from the laboratory shall have a minimum door width of 36 inches to facilitate departure in the event of an emergency.

24 CCR 2 1003.3.1.3a1.

2. Laboratories having a floor area of 200 square feet (18.6 m²) or more need two separate exits. All portions of the laboratory must be within 75 feet of an exit.

24 CCR 2 1007.4.1 (for H-8 occupancies)

3. Lab benches, furniture, or obstacles shall be placed so that there is at least 5 feet of clear egress.

Good Practice

Lab benches shall not impede emergency access to an exit. This is also applicable to placement of other furniture and appliances such as chairs, stools, refrigerators, etc.

4. The space between adjacent workstations and laboratory benches should be 5 feet or greater to provide ease of access. In a teaching laboratory, the desired spacing is 6 feet. Bench spacing shall be considered and included in specifications and plans.

*ADA 42 USC 12111 9(A), 12183
NFPA 45, Chapters 2 and 3*

1. General Requirements for Laboratories

5. Spaces between benches, cabinets, and equipment shall be accessible for cleaning and to allow for servicing of equipment.

Good Practice

NIH Biosafety in Microbiological and Biomedical Laboratories, BSL 2, D.4

NIH Guidelines for Research Involving Recombinant DNA Molecules, App. GII-B-4-c

Laboratory furniture should have smooth, nonporous surfaces to resist absorbing liquids, and to decrease vulnerability to the harsh effects of disinfectants. Furniture shall not be positioned in a manner that makes it difficult to clean spilled liquids or to conduct routine maintenance.

6. The laboratory doors are to be automatically self-closing.

24 CCR 2, Chapter 10

Prudent Practices in the Laboratory, Section 5.C

24 CCR 9 (CFC) 1007.4.37.

ADA

The self-closing laboratory doors are to be able to be opened with a minimum of effort as to allow access and egress for physically challenged individuals.

7. All exit and emergency doors serving hazardous occupancies shall swing in the direction of exit travel, regardless of the occupant load, and shall be equipped with panic hardware.

24 CCR 2, Chapter 10

Prudent Practices in the Laboratory, Section 5.C

24 CCR 9 (CFC) 1007.4.4, 1007.4.5

G. Electrical and Utility Issues

1. The lab shall be fitted with electrical outlets that can accommodate current requirements with an additional 20 to 40% capacity.

Good Practice

The lab may have several pieces of equipment that require large amounts of electrical current. Such items include freezers, biosafety cabinets, centrifuges, and incubators.

2. Circuit breakers should be located outside the lab, but not in rated corridors.

Good Practice

In the event of an emergency, the laboratory may be unsafe to enter. ICBO recommends not putting electrical panels in rated corridors.

3. Electrical receptacles above countertops and within 6 feet of sinks or other wet areas should have GFCI circuit protection. Receptacles that are not readily accessible or receptacles for appliances occupying dedicated space that are cord-and-plug connected in accordance with NEC Section 400-7A (6–8) are excepted from this requirement.

NFPA 70, Chapter 2, 210–8

4. Main valves for gas and vacuum lines should be located outside the lab, e.g.,

1. General Requirements for Laboratories

elsewhere on the floor or in a mechanical room.

Good Practice

In the event of an emergency, the laboratory may be unsafe to enter. Hence, the valves for gas and vacuum lines should be located outside the lab. See also Chapter 1, Section I (Nonstructural Seismic Hazard Abatement).

5. Flexible connections shall be used for connecting gas and other plumbed utilities to any freestanding device, including but not limited to biosafety cabinets, incubators, and liquid nitrogen freezers.

Good Practice

Seismic activity may cause gas and other utility connections to the biosafety cabinet to break off. Leaking natural gas is a fire hazard, and flexible connections minimize this potential hazard.

See also Chapter 1, Section I (Nonstructural Seismic Hazard Abatement).

H. Accessibility

Laboratory design should include adapted workbenches as necessary, especially in teaching laboratories. It is preferable to have an adjustable workbench to allow for differently abled individuals.

- A work surface that can be adjusted to 27 to 37 inches from the floor
- A 29-inch clearance beneath the top to a depth of at least 20 inches
- A minimum width of 36 inches to allow for leg space for the seated individual
- The utility and equipment controls are placed within easy reach

ADA, Title III Public Accommodations and Services Operated by Private Entities Sec. 303. New Construction and Alterations in Public Accommodations and Commercial Facilities.

I. Nonstructural Seismic Hazard Abatement

1. All shelves shall have a passive restraining system such as seismic shelf lips (3/4 inch or greater). The shelves themselves shall be firmly fixed so they cannot be vibrated out of place and allow the shelf contents to fall.

Prudent Practices in the Laboratory, Sections 4.E.1 and 4.E.2

Good Practice

Installation of seismic lips on shelving areas will prevent stored items from falling during a seismic event.

2. Flexible connections are preferred for connecting equipment and devices to utilities to allow for relative movement in a severe earthquake.

Good Practice

Seismic activity may cause gas and other utilities to break off. A flexible connection will minimize this potential.

3. Any equipment, including but not limited to, appliances and shelving to be installed by the contractor, which is 42 inches or higher and has the potential for falling over during an earthquake, or moving and blocking corridors or doors, shall be

1. General Requirements for Laboratories

permanently braced or anchored to the wall and/or floor.

24 CCR 2 Table 16A-O

8 CCR 3241

4. All compressed gas cylinders in service or in storage shall be secured to substantial racks or appropriate, sufficiently sturdy storage brackets with two chains, straps, or the equivalent, at 1/3 and 2/3 of the height of the cylinders to prevent their being dislodged during a violent earthquake. NOTE: Clamping devices are not acceptable as cylinder restraints.

Prudent Practices in the Laboratory, Section 4.E.4

8 CCR 4650

Good Practice

See Chapter 5 of this document for pressure-vessel and compressed-gas design concerns.

J. Teaching Laboratories

Undergraduate chemistry courses are faced with introducing large numbers of inexperienced people to handling hazardous materials. Often, the student's immediate supervisor is a graduate student teaching assistant (TA). The level of teaching ability, experience, and communication skill between TAs varies widely. Therefore, it is very important to provide a quiet facility with clear sight lines, more than sufficient room to move about, and chemical storage devices that are securable, safe, obvious, and well labeled.

1. Adequate laboratory fume hoods shall be provided. A facility designed for intensive chemistry use should have at least 2.5 linear feet of hood space per student. Less intensive applications should have hood space adequate for the anticipated number of students.

Prudent Practices in the Laboratory, Section 8.C.4

Good Practice

See Chapter 3 of this document for hood specifications.

2. Noise levels at laboratory benches shall not exceed 55 dBA to help provide the ability to see and hear the instructor from each student's workstation.

Prudent Practices in the Laboratory

Good Practice

Students shall be able to follow the safety, health, and emergency information during the laboratory class period. It is very important to minimize the background noise, principally from air handling.

3. Combined eye wash/safety shower units shall be placed so they are visible and easily accessible to all of the students in the lab. Clearly mark or indicate, with a different floor design, the area beneath the shower and in front of the eye wash that is to be kept open.

Good Practice

See Chapter 4 of this document for eyewash/safety shower issues.

Students and janitors should not place objects blocking showers.

2. ELECTRICAL SAFETY

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A. Scope

This guide addresses some of the most common issues affecting the appropriate and safe installation of electrical systems for research laboratories. It is not intended to include all electrical installation requirements or good practices. As such, it does not include comprehensive guidance on standard architectural practices or all building code requirements, but presents special issues identified by electrical safety experts working primarily in a research environment.

B. General Design Guidelines

1. 120-volt receptacles should be located on every open wall such that there is not more than 6 feet of wall space to a given receptacle. Quad outlet boxes are preferred over duplex. Lab bench areas should be equipped with continuous receptacle molding (e.g., Plugmold) strips with receptacles spaced on 6–12-inch centers, or similarly continuous receptacles in raceway.

8 CCR 2500.7

One of the most common electrical shock and fire hazards is the overuse of extension cords and various receptacle multipliers. The designer can preclude this hazard by anticipating a heavy need for receptacles everywhere in the laboratory space. In research laboratories, it is rare to have too many receptacles.

2. Ceiling-mounted, pendant drop receptacles or floor-mounted receptacles should be provided as needed for laboratories where equipment will be located away from walls.

8 CCR 2500.7

Cords crossing floors create tripping and shock hazards. Cords and caps must be provided with strain relief. For any receptacle mounted on a horizontal work surface, a monument style is preferred over flush mount to minimize the risk of liquid inundation.

3. Provide receptacles of appropriate voltage and current ratings for known equipment in addition to the general convenience receptacles noted above.

8 CCR 2390.1

NFPA 70

Good Practice

To avoid overloading circuits, calculate the sum of all known loads separately from the convenience outlet loads.

4. Ground Fault Circuit Interrupter (GFCI) protection must be provided for

2. Electrical Safety

convenience receptacles located within 6 feet of a sink or other wet location. GFCI receptacles should not be used for critical equipment such as refrigeration, sump pumps, or gas detectors. Use dedicated single receptacle outlets for such equipment.

NFPA 70

Even though the code requirements for GFCIs are not very extensive, these inexpensive devices are among the most effective measures that can be taken to prevent electric shock.

5. Provide GFCI protection for receptacles that feed vessel-heating equipment such as strip heaters for vacuum vessels.

NFPA 70

A fault from a strip heater to a large metal object such as a vacuum vessel poses a significant risk of shock. In addition, strip heaters are typically two-wire without ground, and the only overcurrent protection that can be provided is GFCI.

6. Adequate clear space must be provided in front and to the sides of each electrical circuit breaker panel and equipment disconnect. Label each circuit breaker panel and similar equipment with requirements to maintain a clear 30-inch-wide x 36–48-inch-deep space (depending on voltage).

8 CCR 2340.22

NFPA 70

Good Practice

Chapter 1 of NFPA 70 contains the requirements for maintaining clear working space around electrical equipment. The label is not specifically required by Code, but is a good practice in areas where equipment and supplies are frequently being moved around. An even better practice is to also mark floors with durable lines, preferably diagonally striped.

7. Each circuit breaker panel and similar equipment shall be labeled with a notification of an electrical arc flash hazard.

NFPA 70

A requirement added to the Code in 2002 mandates a warning label where an arc hazard exists. In open panels and similar equipment, an unprotected worker can be exposed to lethal energy levels if an arc is generated.

8. Circuit-breaker panels should not be located in the laboratory.

Good Practice

Panels require a maintained, clear floor space of approximately 9 square feet. Typically, wall and floor space are very valuable in laboratories for research equipment. See number 6, above, for additional information about these spaces.

9. Each circuit and circuit breaker must be sized to carry no less than 100% of the noncontinuous current load plus 125% of the continuous current load for that circuit.

NFPA 70

2. Electrical Safety

Chapter 2 of the Code outlines the correct methods for sizing circuit conductors and overcurrent devices.

10. Laboratory convenience receptacle circuits should be sized as 20 amp circuits, with no more than 13 duplex devices per circuit.

NFPA 70

Good Practice

The minimum 15-amp circuit size is usually inadequate for laboratory applications. Convenience outlets are calculated at 180VA per device.

11. When designing circuit-breaker panels, at least 20–40% additional load capacity and circuit-breaker spaces than required by initial calculations should be provided.

NFPA 70

Good Practice

The Code suggests engineering room for system growth.

12. Circuit-breaker panels with built-in lockout devices for each breaker should be specified.

8 CCR 2320.4

All electrical circuits are required to be lockable for maintenance purposes.

13. Fixed equipment that requires periodic maintenance should be provided with lockable disconnect points (safety switch).

8 CCR 2320.4

All electrical equipment is required to be lockable for maintenance purposes. Exception: cord and plug connected equipment.

14. Electrical equipment and controls within fume hoods should be provided with a disconnect switch within 15 feet.

NFPA 45

This does not apply if the equipment is plug-connected outside of the hood.

15. Electrical receptacles and switches should be located to minimize their exposure to spilled liquids.

NFPA 45

Do not place strip receptacles (“Plug Mold”) across the front of a chemical fume hood below the work surface. Mounting additional receptacles to the side of the fume hood is preferable.

16. Each branch circuit should carry its own neutral conductor. Do not use multiwire branch circuits that share a grounded (neutral) conductor.

NFPA 70

Good Practice

The increasing use of electronic equipment introduces harmonic loading onto circuits. In a shared-neutral configuration, these harmonics can result in dangerous conductor overheating.

2. Electrical Safety

17. Each conduit should carry a green insulated equipment grounding conductor.

Good Practice

Although a metal conduit may be considered acceptable as an equipment grounding conductor, it is best to supplement this with a copper wire equipment ground. This will provide a lower impedance path, and will ensure grounding integrity if the conduit fittings become loose over time.

18. Circuits serving sensitive Information Technology or data acquisition equipment should be provided with an isolated grounding conductor in addition to the required equipment grounding conductor. This isolated conductor is to be terminated in an identified isolated receptacle or within the sensitive equipment.

NFPA 70

Good Practice

It is important to understand that the isolated ground, if desired, must be run in the same raceway with the circuit conductors. Under no circumstances may the earth serve as the sole ground return pathway.

19. Electrical wiring and equipment meeting the specific requirements of NFPA 70, Chapter 5, for classified locations must be provided if substances used or stored in the laboratory can create a flammable or explosive atmosphere.

NFPA 70, 30, 33, 34, 35, 45, 497, 499

“Explosion-proof” wiring requires careful engineering and collaboration between experts in fire safety and electrical codes.

20. Rated clamps and conductors shall be provided to adequately bond containers, hoses, and other dispensing equipment to each other and the grounding system where flammable liquids are to be dispensed.

NFPA 77

Static electricity must be controlled in dispensing areas.

21. Electrical power shall not be commingled in a cable tray with other utilities (e.g., electrical, gas, water, etc.).

NFPA 70

Cable trays are used in many labs to organize wiring and other utilities. These can be useful in controlling trip hazards and housekeeping problems, but they are regulated by the Code. Water and gas lines may be run below the cable tray provided that they are not attached to the tray itself. Trays may be stacked to provide space for power in the upper tray and other utilities in the lower tray.

22. Electrical equipment shall be designed and installed such that there is no possibility for a person to make direct contact with any part that may become energized at 50 volts or greater during normal use. Exceptions may be made where the possible exposure current cannot exceed 5 milliamps.

8 CCR 2340.17

2. Electrical Safety

The possibility for electrocution is generally agreed to exist by contacting 50 volts or greater. All such exposures should be controlled by confinement within an enclosure, substantial guarding, isolation, or special interlocks that render the installation safe before contact can be made.

23. Electrical drawings should be carefully coordinated with other disciplines to assure that conflicts do not occur.

Good Practice

The Code provides very strict rules on clearances, placement of switches, etc. and especially with wiring recessed within a wall, can be very expensive to correct.

C. Pre-Commission Evaluation Acceptance

Due to the potential for shock, serious injury, and fire, laboratories shall be inspected and approved by a qualified UC staff electrical safety expert prior to beginning work.

3. LABORATORY VENTILATION AND FUME HOODS

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A. Scope

The purpose of this standard is to set forth the requirements for new or retrofit laboratory and fume hood ventilation. This standard is to be considered the minimum requirement; more stringent requirements may be necessary, depending on the specific laboratory function or contaminants generated.

B. General Laboratory Ventilation Design Issues

The primary functions of ventilation systems are to provide safe, comfortable, breathable environments for all employees and the public, and to minimize exposures to hazardous air contaminants. Careful planning, designing, and maintaining air supply and exhaust vents and equipment can accomplish these goals. Laboratory fume hoods function only as well as allowed by the designs of the air supply system and fume hood, and the ability of the operator. EH&S may specify and shall approve any additional controls (e.g., local exhaust ventilation) needed to control hazardous chemical exposures. The users, their EH&S support staff, and the designers must agree on the design of the ventilation system. Any management approach that eliminates the process of mutual agreement risks mistakes that may be costly to live with and correct later.

1. All laboratory spaces shall have mechanically generated and conditioned supply and exhaust air. All lab rooms shall exhaust 100% to the outside. There shall be no

3. Laboratory Ventilation and Fume Hoods

return of fume hood and laboratory exhaust back into the building.

Air exhausted from a clean room may be HEPA filtered and resupplied to that same clean room provided that the recirculated air does not contain volatile hazardous materials.

Prudent Practices in the Laboratory, Sections 8.C and 8.D

Good Practice

24 CCR, Part 3, 505.3

2. Special laboratory chemical hoods, as well as other devices equipped with ventilation to protect workers, the public, or the environment, shall be designed in accordance with ANSI/AIHA Z9.2 and ACGIH's *Industrial Ventilation: A Manual of Recommended Practice*.

ANSI Z9.5 4.3

3. Sufficient exhaust air shall be provided to assure the removal of hazardous airborne materials. In general, hazardous operations should be enclosed in fume hoods or other exhausted enclosures. The total volume of exhaust air shall be a minimum of 1 cfm/square foot of floor area. When fume hoods are installed, they must operate continuously and may not be controlled by switches.

When air is exhausted from a laboratory in a volume that exceeds 1 cfm/square foot (for example, in a room with multiple fume hoods), the exhaust volume may be reduced during periods when the room is unoccupied, provided that sufficient volume is maintained to exhaust hazardous materials, and the reduced volume does not fall below 1 cfm/square foot.

Historically, the measurement "air changes per hour (ach)" has been used as a design criterion for laboratory ventilation, with recommended values between 6 and 12 ach. This is not an appropriate concept for designing contaminant control systems, as it implies that general laboratory ventilation will be utilized to remove contaminants. Contaminants must be controlled at the source. 1 cfm/square foot of floor area is equivalent to 6 ach for a room with a 10-foot ceiling. Lacking other information, floor area is a rough surrogate for intensity of activity.

Good Practice

ASHRAE Handbook of Fundamentals, Chapter 13

NFPA Article 80

Prudent Practices in the Laboratory, Section 8.C.11

4. Laboratory exhaust systems should be designed with at least 25% excess capacity for future expansion.
5. Avoid generation of excessive noise in laboratory ventilation systems. Fan location and noise treatment shall provide for sound pressure level (SPL) in conformance with local ambient noise criteria. Noise generated by the functioning fume hood within 6 inches of the plane of the sash and bypass opening in any position shall not exceed 60 dBA. The noise level in the general laboratory space should not exceed 55 dBA, which is consistent with good office design, to allow for easy verbal communication.

ANSI Z9.5 5.1.3

3. Laboratory Ventilation and Fume Hoods

Good Practice

The primary references for acoustic design criteria and methods will be found in ASHRAE publications such as the *ASHRAE 1997 Handbook of Fundamentals*, and from the *ASHRAE 1999 HVAC Applications*.

6. The airflow velocity in each duct shall be sufficient to prevent settlement of liquid or condensable solids on the walls of the ducts. A duct velocity of 1,000 fpm seems to be adequate to prevent condensation in fume hood ducts without excessive noise. However, higher velocities are needed to entrain solids.

ACGIH, Industrial Ventilation: A Manual of Recommended Practice (latest edition)

7. Exhaust from hoods used for teaching should be routed to blowers different from those used to exhaust air from research areas.

Good Practice

This allows energy savings for those times when the teaching labs are not being used.

8. Operable windows in laboratories are strongly discouraged. Drafts from open windows can seriously disrupt fume hood containment, and open windows destroy negative pressure containment that should be provided in laboratories (see Section D, below).
9. Flexible local exhaust devices (e.g., “snorkels” or “elephant trunks”) shall be designed to adequately control exposures to hazardous chemicals. An exhausted manifold or manifolds with connections to a local exhaust may be provided as needed to collect potentially hazardous exhausts from gas chromatographs, vacuum pumps, excimer lasers, atomic absorption instruments, or other equipment that can produce potentially hazardous air pollutants. The contaminant source needs to be enclosed as much as possible, consistent with operational needs, to maximize control effectiveness and minimize air handling difficulties and costs.

ACGIH, Industrial Ventilation: A Manual of Recommended Practice (latest edition)

Enclosure minimizes the volume of airflow needed to attain any desired degree of contaminant control. This reduces fan size, motor horsepower, makeup air volume, and makeup air-conditioning costs.

10. Fume hoods shall not be located adjacent to an exit unless a second exit or another means for exiting is provided.

NFPA 45, Chapter 6-9.2

NFPA 45, Chapter 3-4.1(d)

A fire, explosion, or chemical release, any one of which may start in a fume hood, can block an exit, rendering it impassible. Pedestrian traffic can also interfere with the functioning of a hood.

11. Hoods shall be labeled to show the fan or ventilation system to which they are connected.

C. Variable Air Volume (VAV) Systems

1. Variable Air Volume (VAV) systems should be considered to

3. Laboratory Ventilation and Fume Hoods

- Reduce laboratory operating costs, including energy use, while providing adequate ventilation to protect workers; and
- Maintain a constant air velocity into the hood, regardless of sash height.

If a VAV supply system is not feasible, a local variable room exhaust bypass on the fume hood exhaust system can be installed to provide constant face velocity.

2. Campus EH&S organizations should develop specific policies regarding diversity, based on the unique characteristics and needs of the individual campus. Decisions concerning diversity shall be based on:

- Use patterns of hoods
- Type, size, and operating times of facility
- Quantity of hoods and researchers
- Sash management (sash habits of users)
- Requirements to maintain a minimum exhaust volume for each hood on the system
- Type of ventilation system
- Type of laboratory chemical hood controls
- Minimum and maximum ventilation rates for each laboratory
- Capacity of any existing equipment
- Expansion considerations
- Thermal loads
- Maintenance department's ability to perform periodic maintenance

An alarm system shall be installed to warn users when the system is operating beyond the capabilities allowed by system diversity.

ANSI Z9.5 5.1.2

3. Pressure independent constant volume or variable volume air valves for supply and exhaust shall be provided for pressurization control and continuous air balance control. The air balance shall also be maintained during the night setback/unoccupied schedule.

Good Practice

4. The mechanism that controls the exhaust fan speed or damper position to regulate the hood exhaust volume shall be designed to ensure a minimum exhaust volume equal to the larger of 50 cfm/ft of hood width, or 25 cfm/ft² of hood work surface area, except where a written hazard characterization indicates otherwise, or if the hood is not in use.

ANSI Z9.5 3.3.1

5. VAV hoods shall be provided with an emergency switch that allows the hood exhaust volume to go to a maximum flow velocity.

ANSI Z9.5 5.3.2.4

D. Negative Pressurization

1. Airflow shall be from low-hazard to high-hazard areas.

3. Laboratory Ventilation and Fume Hoods

Good Practice

CDC-NIH Biosafety in Microbiological and Biomedical Laboratories

Prudent Practices in the Laboratory, Sections 8.C and 8.D

NFPA 45, 6.4.4

Anterooms may be necessary for certain applications, such as clean rooms or tissue culture rooms. Potentially harmful aerosols can escape from the containment of the laboratory room unless the room air pressure to adjacent nonlaboratory areas is negative.

2. The laboratory airflow control system shall continuously determine supply airflow and exhaust airflow, and by comparing these values, shall ensure design lab pressurization is maintained. A room offset value of 10% of the maximum air value to the room is recommended, or 100 cfm, whichever is greater.

NFPA 45, 6–4.4

See Section B(1) of this chapter.

3. If laboratory pressurization becomes critical to prevent undesirable airflow from one area to another in high-hazardous applications, an airlock may be necessary. Consult EH&S for guidance.

ANSI Z9.5 5.1.1.1

4. A corridor shall not be used as a plenum.

E. Manifolding

1. General fume hood exhausts may be manifolded together. Perchloric/hot acid and other hoods exhausting highly reactive, incompatible or highly toxic materials shall not be manifolded; they shall be exhausted directly to the outside. Hoods requiring HEPA filtration or other special exhaust cleaning shall have a dedicated exhaust system. Radioisotope hoods may be manifolded with nonradioisotope hoods at the discretion of the Radiation Safety Officer.

2. Exhaust streams that may contain flammable or explosive vapors at concentrations above the Lower Explosion Limit as well as those that might form explosive compounds (i.e., perchloric acid hood exhaust) shall not be connected to a centralized exhaust system. If any exhaust stream may contain greater than 20% of the lower flammable limit of a flammable/combustible vapor or dust, sprinklers may be required.

8CCR 5154.1

ANSI Z9.5 5.3.2.3

3. Unless all individual exhausts connected to the centralized exhaust system can be completely stopped without creating a hazardous situation, provision shall be made for continuous maintenance of adequate negative static pressure (suction) in all parts of the system.

ANSI Z9.5 5.3.2.4

This requirement could be satisfied by one or both of the following provisions:

- Multiple operating fans so the loss of a single fan does not result in the loss of total system negative static pressure.

3. Laboratory Ventilation and Fume Hoods

- Spare centralized system exhaust fan(s) that will rapidly and automatically be put into service upon failure of an operating fan by repositioning isolation dampers, and energizing the standby fan motor.

Emergency backup power should be provided to all exhaust fans and the associated control system.

4. For systems with multiple hoods and exhaust fans, adequate redundancy shall be built into the design. This shall be done by either providing 75% capacity with the largest exhaust fan out of service; or providing a redundant fan equal to the capacity of the largest unit.

Good Practice

5. Neither fire dampers nor fire sprinklers shall be installed in chemical hood exhaust system manifolds.

ANSI Z9.5 5.3.2.9 and 5.3.2.10

Studies of actual exhaust systems have demonstrated that the spray cone produced by sprinkler heads can actually act as a damper and reduce or prevent airflow in the duct past the sprinkler head. Like a fire damper, this may produce a lack of flow at one or more laboratory chemical hoods at the moment when it is needed most.

F. Room Airflow/Pressure Control Devices and Control Systems

1. All laboratories should contain a fully integrated laboratory variable air volume (VAV) airflow/pressure control system to control room temperature, ventilation rate and room pressurization. The control system should constantly monitor the amount of supply and exhaust air for the laboratory rooms, and regulate the flow to maintain a net negative pressurization.

Good Practice

2. The control system shall allow easy, remote adjustment of laboratory airflow, and shall be sufficiently flexible to provide timed schedules, local override, reduction of setbacks, or increase of room ventilation if needed for proposed future laboratory operations.

Good Practice

3. The laboratory VAV control system shall perform the following functions:
 - Monitor the hood sash opening and control the cfm volumetric flow rate of that hood to maintain a constant face velocity.
 - If an unoccupied mode of operation is desired, it shall be controlled by a room occupancy (not a hood occupancy) sensor, and shall supply not less than 60% of occupied operational levels of volumetric flow rate.
 - Monitor the fume hood exhaust airflow, the general exhaust airflow and the supply (makeup) airflow, and maintain a net negative airflow so the volume of fresh air entering the space is equal to 90% of the maximum exhaust airflow. Alternatively, a direct pressure control may be used to maintain the laboratory negative pressure at -0.02 to -0.05 " wc relative to nonlaboratory spaces.

3. Laboratory Ventilation and Fume Hoods

- Delay throttling back room air supply for 10 (or more) minutes after the room occupancy sensor no longer detects people in the room (see above).
- The fume hood motion sensor time delay (from attended mode to standby mode) shall be 5–10 minutes to alleviate the nuisance noise and wear and tear from opening/closing the VAV venturi valve/control device too frequently.

Good Practice

4. The associated laboratory airflow control system shall be able to maintain the average fume hood face velocity at the set point specified by the University, typically 100 fpm.

Good Practice

8 CCR5154.1 (c)

See Section N of this chapter for face velocity specifications.

5. Fume hood controls shall be arranged so that shutting down one fume hood for maintenance will not reduce the exhaust capacity or create an imbalance between exhaust and supply for any other hood manifolded to the same system.

Good Practice

6. Redundant airflow monitoring devices may be necessary when airflow direction is critical, such as radiological Type III workplaces.

Good Practice

7. All fan controls for the laboratory VAV control system and hoods shall be stable, reliable, and easily maintained, and readily accessible to facility management, maintenance, and emergency personnel. Sensor measurement range, accuracy, and positioning shall accurately reflect system performance.

NFPA 45 Chapter 6–10.3

Good Practice

8. Per NFPA 45, fume hood exhaust fans shall not be shut down automatically when a smoke-alert signal is detected in the supply air system.

NFPA 45 Chapter 6-10.3

Good Practice

G. Supply Air Arrangements

1. Air intake (and exhaust) grilles shall not be located within an architectural screen or mask unless it is demonstrated to be acceptable. Any architectural structure that protrudes to a height close to the stack-top elevation (i.e., architectural structure to mask unwanted appearance of stacks, penthouses, mechanical equipment, nearby buildings, trees, or other structures) shall be evaluated for its effects on reentrainment. This may require wind engineering calculations or flow simulation studies; see Section J of this chapter for information about wind engineering.

ANSI Z9.5 5.3.5

2. In laboratories maintained with a negative pressurization and directional airflow into the laboratory, supply air volume to the lab shall be less than the exhaust from the laboratory. In laboratories maintained with a positive pressurization and

3. Laboratory Ventilation and Fume Hoods

directional airflow supply, supply air volume shall be more than the exhaust from the laboratory.

ANSI Z9.5 5.2.1

Return air from nonhazardous areas (offices) may be used as makeup air in laboratories, but air exhausted from laboratories may not be returned as supply air to any space (see Section B of this chapter).

3. Room air currents at the fume hood should not exceed 25 fpm to ensure fume hood containment.

Prudent Practices in the Laboratory, Section 8.C

Good Practice

ANSI Z9.5 5.2.2

ANSI Z9.5 suggests that air velocities up to 50 fpm are acceptable, but lower room air velocities around hoods cause less interference with the operation of the hood.

Makeup air should be introduced at low velocity through an opening with large dimensions to avoid creating jets of airflow. An alternative is to direct air towards the ceiling that will allow the air velocity to decrease by the time it approaches a hood.

4. Locate hoods away from activities or facilities that produce air currents or turbulence, e.g., high pedestrian or vehicular traffic areas, air supply diffusers, doors. Air supplied to a laboratory space shall keep temperature gradients and air turbulence to a minimum, especially near the face of the laboratory fume hoods and biological safety cabinets. The air supply shall not discharge on a smoke detector, as this slows its response.
5. Makeup air shall be introduced at the opposite end of the laboratory room from the fume hood(s), and flow paths for room HVAC systems shall be kept away from hood locations, to the extent practical.

NFPA 45, Chapter 6-3.4 and 6-9.1

NIH Research Laboratory Design Policy and Guidelines D.7.7

ANSI Z9.5

Air turbulence defeats the capability of hoods to contain and exhaust contaminated air.

6. Makeup air shall be introduced in such a way that negative pressurization is maintained in all laboratory spaces and does not create a disruptive air pattern.

Good Practice

7. Cabinetry or other structures or equipment shall not block or reduce the effectiveness of supply or exhaust air.

Good Practice

8. Supply system air should meet the technical requirements of the laboratory work, and the requirements of the latest version of ASHRAE, Standard 62, *Ventilation for Acceptable Indoor Air Quality*. Nonlaboratory air or air from nonhazardous building areas adjacent to the laboratory may be used as part of the supply air to the laboratory if its quality is adequate.

3. Laboratory Ventilation and Fume Hoods

*ANSI Z9.5 5.2.3 and 5.3.6
Good Practice*

H. Ducting

1. Systems and ductwork shall be designed to maintain negative pressure within all portions of the ductwork inside the building when the system is in operation.
2. Exhaust ductwork shall be designed in accordance with ANSI/AIHA Z9.2-2001, Chapter 32 of the *ASHRAE 1997 Handbook of Fundamentals*, and Section 6-5 of NFPA 45-2000.
3. Laboratory exhaust system ductwork shall comply with the appropriate sections of Sheet Metal and Air Conditioning Contractors' National Association (SMACNA, 1985) standards.
4. Exhaust ductwork shall be fire- and corrosion-resistant and selected based on its resistance to the primary corrosive present. Exhaust system materials shall be noncombustible if perchloric acid or similar oxidizing agents that pose a fire or explosion hazard are used.

ANSI Z9.5 5.3.1.2

8 CCR, 5154.1 (e)(7)

24 CCR, Part 4, 609.1

NFPA 45, Chapter 6-5.1

ASHRAE Handbook of Fundamentals, Ch. 32

ACGIH Industrial Ventilation: A Manual of Recommended Practice, Ch. 5

Refer to the campus architect's and engineer's design criteria for specific fume hood fan and motor requirements. Welded Type 316L stainless steel is often used, but may be attacked by some corrosive materials. Stainless steel is particularly inappropriate where vapors of hydrochloric acid will be present due to a chloride attack, or where vapors of nitric acid may be present. Galvanized steel coated inside and out with a 4 mL thick coating of polyvinyl chloride, or a corrosion-resistant epoxy coating, may be an acceptable material for fume exhaust ductwork; under certain circumstances, fiberglass-reinforced plastic (UL rated) may be used as an alternative. The campus ES&H organization can be consulted for advice on compatible materials.

5. Exhaust ductwork joints shall be sealed to protect against a chemical attack.
6. Slope all horizontal ducting down towards the fume hood (recommended guideline: slope equals 1 inch to 10 feet).

ANSI Z9.5 5.3.1.1

Good Practice

Liquid pools and residue buildup that can result from condensation may create a hazardous condition if allowed to collect. In cases where dust or high concentrations of solids might accumulate, such accumulation within the duct system may be prevented by providing water spray nozzles in the duct at frequent intervals and sloping the duct down to an appropriate receptor (e.g., a wet dust collector).

3. Laboratory Ventilation and Fume Hoods

7. The exhaust ducting shall be grounded to dissipate any static electricity. Lengths of electrically conductive ductwork on both sides of a flex connection or other insulating section in the airflow path shall be electrically bonded and grounded.

Good Practice

8. Laboratory supply ventilation system ductwork shall not be *internally* insulated. Sound baffles or external acoustical insulation at the source should be used for noise control.

Occupational Exposure, Toxic Properties, and Work Practices Guidelines for Fiberglass, AIHA

Good Practice

Fiberglass duct liner deteriorates with aging and sheds into the space resulting in indoor air quality (IAQ) complaints, adverse health effects, maintenance problems, and significant economic impact. Glass wool and refractory ceramic fibers are classified as possible carcinogens by the National Toxicology Program.

9. Exhaust airflow volume shall be sufficient to keep the temperature in the duct below 400°F (205°C) under all foreseeable circumstances.

ANSI Z9.5 5.3.1.1

This includes the ignition of a flammable liquid spill that in turn requires an estimate of the maximum credible accident that would generate heat.

If variable air volume (VAV) laboratory chemical hoods are used, satisfying these criteria might require a heat sensor arrangement to signal the VAV controls system to increase the exhaust airflow. An alternative solution would be to provide a higher-temperature exhaust system design or a high-temperature combustion flue design for the portions of the exhaust system in which temperatures might exceed 400°F (205°C) in conjunction with NFPA 86–1999.

I. Exhaust Fans and Systems

1. Treatment (i.e., filtration, scrubbing, etc.) is generally not required for laboratory and fume hood exhaust systems due to high dilution within the systems.

Exceptions include:

- Perchloric/hot acid digestion hoods where a water wash system is required, and
- Systems conveying radioactive or biological exhaust streams where HEPA filtration is required.

When modeling or use estimates show that airborne levels of hazardous chemicals would exceed exposure limits at the point of discharge or exceed applicable community exposure levels at ground level, exhaust stream treatment may be required. Note also that a source control may also be necessary when modeling catastrophic releases of gases classified as “toxic” or “highly toxic” using local codes.

2. Exhaust fans shall be oriented in an up-blast orientation. Rain caps, bird screens,

3. Laboratory Ventilation and Fume Hoods

and goosenecks are prohibited.

Good Practice

ASHRAE Handbook of Fundamentals, Chapter 14

Any other type of fan orientation increases the fan workload and increases the risk of exhaust emission reentrainment. See the above ASHRAE reference for more guidance about rain protection that does not interfere with exhaust fan function.

3. Laboratory ventilation exhaust fans shall be spark-proof and constructed of materials or coated with corrosion-resistant materials for the chemicals being transported. V-belt drives shall be conductive.

NFPA 45

Good Practice

Corrosion-resistant materials reduce the cost of ownership and should be used for this reason alone. In addition, they can prevent the development of unsafe situations due to loss of structural integrity, leakage into or out of ductwork, etc.

4. Fans should be provided with:

- Outboard bearings,
- A shaft seal,
- An access door, and
- Multiple 150-percent-rated belts or direct drives, unless there are demonstrated sound reasons not to use them.

Good Practice

5. Laboratory exhaust fans shall be located as follows:

- Physically outside of the laboratory building and preferably on the highest-level roof of the building served. This is the preferred location since it generally minimizes the risk of personnel coming into contact with the exhaust airflow.
- In a roof penthouse or a roof mechanical equipment room that is always maintained at a negative static pressure with respect to the rest of the facility, providing direct fan discharge into the exhaust stack(s).

Each fan shall be the last element of the system so that the ductwork through the building is under negative pressure.

Good Practice

NFPA 45

ANSI Z9.5

6. All laboratory exhaust fans shall include provisions to allow periodic shutdown for inspection and maintenance. Such provisions include:

- Ready access to all fans, motors, belts, drives, isolation dampers, associated control equipment, and the connecting ductwork. It shall not be necessary for workers to enter a plenum.
- Isolation dampers on the inlet side of all centralized exhaust system fans that have individual discharge arrangements or their own individual exhaust stacks.
- Isolation dampers on both the inlet and outlet sides of all centralized exhaust system fans that discharge into a common exhaust stack or plenum.

3. Laboratory Ventilation and Fume Hoods

- Sufficient space to allow removal and replacement of a fan, its motor, and all other associated exhaust system components and equipment by personnel using PPE without affecting other mechanical equipment or the need to alter the building structure.

ANSI Z9.5 5.3.3

NFPA 45

If a centralized exhaust system has multiple fans, and a fan replacement is necessary, the process should not require disconnecting piping or removing other building encumbrances that might lead to an indefinite postponement of the required work.

7. Vibration isolators shall be used to mount fans. Flexible connection sections to ductwork, such as neoprene-coated glass-fiber cloth, shall be used between the fan and its intake duct when such material is compatible with hood chemical use factors.

Good Practice

8. Each exhaust fan assembly shall be individually matched (cfm, static pressure, brake horsepower, etc.) to each laboratory ventilation system.

ACGIH Industrial Ventilation: A Manual of Recommended Practice

J. Building Discharge and Wind Engineering

1. Building discharges shall be located and designed in accordance with Chapter 14 of the *ASHRAE Handbook of Fundamentals*. Fume hood and other contaminated exhaust shall not be recirculated into the building air supply. Interactions with adjacent buildings and their supply air intake requirements shall be carefully evaluated.

Considerations must be given to a wind-tunnel study to assure that reentrainment of exhaust will not occur, and that potentially hazardous exhaust will not impact nearby buildings.

ANSI Z9.5 5.3.4

ASHRAE 1999 Handbook — HVAC Applications, Chapter 43

ASHRAE Handbook of Fundamentals, Chapter 14

Good Practice

2. Fume hood exhaust should have vertical stacks that terminate at least 10 feet above the roof deck or two feet above the top of any parapet wall, whichever is greater. Higher stacks may be found to be necessary, using the guidance in the *ASHRAE Handbook of Fundamentals*, Chapter 14, and/or based on wind tunnel studies.

ANSI Z9.5 5.3.5

The basic challenge in locating the hood discharge is to avoid re-entrainment of effluent into any building air intake or opening and to minimize exposure of the public. The selection of stack height is dependent on the building geometry and airflow pattern around the building and is as variable as meteorological conditions.

3. Laboratory Ventilation and Fume Hoods

The 10 ft (3 m) height above the adjacent roof line called for by this standard is primarily intended to protect maintenance workers from direct exposure from the top of the stack. However, this minimum 10 ft (3 m) height may be insufficient to guarantee that harmful contaminants won't enter the outside air intake of the building or of nearby buildings.

See Chapter 43 of the *ASHRAE 1999 Handbook — HVAC Applications*. Among the factors to consider in establishing stack configuration, design, and height are: toxicity, corrosivity, and relative humidity of the exhaust, meteorological conditions, geometry of the building, type of stack head and cap design, adjacency of other discharged stacks and building intake, discharge velocity, and receptor population.

3. A minimum discharge velocity of 3,000 fpm is required unless it can be demonstrated that a specific design meets the dilution criteria necessary to reduce the concentration of hazardous materials in the exhaust to safe levels at all potential receptors.

ANSI Z9.5 5.3.4

8 CCR 5154.1(e)(4)

ASHRAE Handbook of Fundamentals, Chapter 14

A discharge velocity of 2,500 fpm (12.75 m/s) prevents downward flow of condensed moisture within the exhaust stack. It is good practice to make the terminal velocity at least 3,000 fpm (15.3 m/s) to encourage plume rise and dilution. These factors affect the dilution of the exhaust stream and the plume trajectory. High-discharge velocity and temperature increase plume rise, but high velocity is generally less effective than increased stack height. Augmented exhausters can be used, e.g., Strobic Air blowers, but the conditions of service need to be considered to avoid subjecting such equipment to conditions that could rapidly damage them.

4. Wind engineering evaluations shall be conducted for all wind directions striking all walls of a building. Actual height and placement shall be confirmed via 3-D modeling in a wind tunnel where building exhaust is likely to have significant ground level impact, or is likely to affect air intake for nearby buildings. Modeling should also be performed when radioactive or carcinogenic materials will be exhausted by the ventilation system.

8 CCR 5154.1(e)(4)(D)

5. Emergency generator exhaust shall be considered in the wind-engineering study.

Good Practice

ASHRAE Handbook of Fundamentals, Chapter 14

Combustion product odor from emergency power units (EPUs) is a significant nuisance. EPUs shall be located remotely or have tall-enough stacks to clear adjacent building air intakes and windows using the one in five rule of thumb mentioned in Chapter 14 of the *ASHRAE Handbook of Fundamentals*.

6. Aesthetic conditions concerning external appearance shall not supersede the requirements of this Section.

ANSI Z9.5 5.3.5

K. Emergency Ventilation

1. When the type and quantity of chemicals or compressed gases that are present in a laboratory room could pose a significant toxic or fire hazard, the room shall be equipped with provision(s) to initiate emergency notification and initiate the operation of the ventilation system in a mode consistent with accepted safety practices.
2. A means such as a clearly marked wall switch, pull station, or other readily accessible device shall be installed to enable the room occupants to initiate appropriate emergency notification and simultaneously activate the ventilation system's chemical emergency (chemical spill, eyewash or emergency shower activation, flammable gas release, etc.) mode of operation if one exists.
 - For rooms served by VAV ventilation systems, the Chemical Emergency mode of operation should maximize the room ventilation rate and, if appropriate, increase negative room pressurization. For rooms served by constant air volume (CAV) ventilation systems that utilize a reduced ventilation level for energy savings, the Chemical Emergency mode of operation should ensure that the room ventilation and negative pressurization are at the maximum rate.
 - Operation of the room ventilation system in a chemical emergency mode should not reduce the room ventilation rate, room negative pressurization level, or hood exhaust airflow rate.
3. A means such as a wall-mounted "FIRE ALARM" pull station or equivalent shall be installed to enable the room occupants to initiate a fire alarm signal and simultaneously activate an appropriate fire emergency mode of operation for the room and/or building ventilation system.

For rooms served by VAV ventilation systems, the fire emergency mode of operation should maximize the exhaust airflow rate from the hoods and other room exhaust provisions, and also reduce the room supply makeup air. For rooms served by CAV ventilation systems that utilize a reduced ventilation level for energy savings, the fire emergency mode of operation should ensure that the maximum exhaust airflow rate from the hoods and other room exhaust provisions are in effect, and should also reduce the room supply makeup air.

Note, however, that ventilation supply/exhaust imbalance can make the doors extremely difficult to open. Consider programming in a short delay into the fire alarm system (30–60 sec or more) between activation of building evacuation alarms, and shifting the ventilation system to the fire-emergency mode of operation. This delay will allow occupants to evacuate prior to making the doors difficult to operate. The sequence of operations of the emergency ventilation response must take into account the possible conflicting needs of smoke containment and emergency egress. The Fire Authority Having Jurisdiction and the local EH&S office must concur on the configuration of the fire emergency mode of operation.

3. Laboratory Ventilation and Fume Hoods

*ANSI Z9.5 5.1.4
Good Practice*

L. Emergency Power

1. Air handlers for chemical fume hoods should be connected to an emergency power system to maintain flow after a power outage. The fans must be configured to auto-restart so that fans will automatically restart upon shifting to emergency power. The overall ventilation system shall provide at least half of the normal airflow during an electrical power failure.

*Prudent Practices in the Laboratory, Section 8.C.4.5
Good Practice*

Required by California Building Code for H occupancies.

2. Losses of power shall not change or affect any of the control system's set points, calibration settings, or emergency status. After power returns, the system shall continue operation, exactly as before, without the need for any manual intervention. Alarms shall require manual reset, should they indicate a potentially hazardous condition.

M. Hoods — Construction and Installation

1. Laboratory hoods shall not have a user-controlled on/off switch. Exhaust fans shall run continuously without direct local control from laboratories.

Good Practice.

The switch could be inadvertently turned off if it is located in the laboratory.

2. New fume hoods shall be from a manufacturer acceptable to the University and specifically approved by the area Industrial Hygienist. All fume hood designs shall demonstrate containment of tracer gas less than 4.0AM0.01 and 4.0AI0.05 when tested according to ASHRAE Test Standard 110-1995.

ANSI Z9.5

3. Variable air volume (VAV) hoods should be used, unless there are sound reasons to not use VAV hoods (e.g., if there are only a few hoods or dedicated single-ducted hoods). In those cases where VAV hoods cannot be used, CAV hoods with bypass air openings shall be used.
4. All hoods shall be equipped with sash stops on vertical rising sashes allowing the sash height to be set at 18 inches during routine use, unless there are sound reasons to use another sash height. Hoods equipped with sash stops should be furnished with an alarm to indicate openings in excess of the design sash opening area.

ANSI Z9.5 3.1.1.1

5. Where CAV hoods are used, the bypass air opening shall not be uncovered until the sash has been lowered to 2/3 of the full opening height. The opening shall progressively and proportionally uncover as the sash is lowered to its lowest point. The face velocity at the lowest sash opening should not exceed three times the

3. Laboratory Ventilation and Fume Hoods

nominal face velocity with the sash open to the operating height. The hood exhaust volume shall remain essentially unchanged (<5% change) when the sash is fully closed.

AIHA Z9.5 3.2.1

6. New hoods may be mounted on a chemical storage cabinet.
Good Practice
7. Underhood storage units shall comply with the guidance of Chapter 6 of this design guide.
8. Interior fume hood surfaces shall be rigid and safe, and be constructed of corrosion-resistant, nonporous, noncombustible materials appropriate for the intended use.
9. The interiors of hoods shall have smooth and impermeable interior surfaces with rounded corners. Interior surfaces should be free of cracks and crevices to provide for easy cleaning.
10. Laboratory hood work surfaces shall be provided with a means of containing minor spills. Generally, a 3/8-inch indentation in the work surface provides adequate containment. Any openings in the work surface, for example, chases for routing hoses to underhood vacuum pumps, shall extend above the top of the work surface containment and be caulked liquid-tight to the work surface.
11. Hoods shall have airfoils and sidewall designs that reduce leakage, and airflow eddies at the front edge of the work area. Airfoils shall not interfere with the hood's ability to meet the criteria of performance testing specified by the University.

Good Practice

AIHA Z9.5 3.1

The airfoil at the front of the hood floor assures a good sweep of air across the work surface toward the back of the hood. This minimizes the generation of turbulence or eddy currents at the entrance to the hood.

12. The rear and top interior of the hood shall be furnished with baffles to provide at least two, preferably three, slots. Baffles should be continuous across the back of the fume hood. Externally adjustable baffles shall not be used.

NFPA 45, Chapter 6-8.1.2

Good Practice

This is in order to attain a reasonably uniform face velocity under various conditions of hood use.

13. All hoods shall be equipped with a flow indicator, flow alarm, or face velocity alarm indicator to alert users to high- and low-exhaust flow. The flow-measuring device shall be capable of indicating airflows at the design flow and $\pm 20\%$ of the design flow. The means of alarm or warning chosen should be provided in a manner readily visible or audible to the hood user. The alarm should warn when the flow is 20% low, and that is 80% of the set-point value. The choice of audible vs. visible alarms shall be made considering the potential needs of a physically disabled user.

3. Laboratory Ventilation and Fume Hoods

ANSI Z9.5 3.3.3
8 CCR 5154.1(e)(3)
NFPA 45, Chapter 6-8.7.1

Excessive face velocity (greater than approximately 125 fpm) can create turbulence and instability within the fume hood. Low face velocity can cause the fume hood to spill under use conditions. The flow monitor and selected should be easily checked for calibration and, if necessary, adjusted. Manufacturer's procedures should be obtained and followed concerning calibration of the flow indicators and alarms.

14. Light fixtures should be of the fluorescent type, and replaceable from outside the hood. Light fixtures should be displaced or covered by a transparent, impact-resistant, vapor-tight shield to prevent vapor contact. Hood lighting shall be provided by UL listed fixtures. If located within the hood interior, the fixtures shall meet the requirements of NFPA 70 (National Electrical Code) sections appropriate for hazardous atmospheres.

NFPA 45, Chapter 3-6
24 CCR California Electrical Code
NFPA 70 National Electrical Code

15. The valves, electrical outlets, and switches for utilities serving hoods shall be placed at readily accessible locations outside the hood. Shutoff valves shall be clearly labeled. Plumbing (e.g., vacuum lines) should exit the sides of the fume hood and not the benchtop.

ANSI Z9.5 3.1
NFPA 45, Chapter 6-8.5.1
Good Practice

16. Hood electrical switches shall have indicator lights.
17. Hoods shall have an individually trapped sink or cup sink, when needed. Backflow preventers or vacuum breakers shall be used to protect domestic water supplies, in accordance with local policies.
18. Drying ovens shall not be placed under fume hoods
19. Supply or auxiliary air hoods are not permitted.

Good Practice

It is very difficult to keep the air supply and exhaust of supply hoods properly balanced. In addition, the supply air is not tempered, causing discomfort for those working in the hot or cold air stream. As a result, the supply vent is often either shut or blocked off, which eliminates any potential benefit of this type of hood. Finally, the presence and movement of the user's body in the stream of supply air creates turbulence that degrades the performance of the hood.

20. Portable, nonducted fume hoods are not permitted.

Good Practice

3. Laboratory Ventilation and Fume Hoods

Portable hoods often do not meet the regulatory airflow requirements. Filters/sorbent beds used with these units shall be changed frequently, and vary in filtration effectiveness from chemical to chemical. Contaminants adsorbed on carbon will also tend to desorb with the passage of time, and the lifetimes of the sorbent beds can not be readily predicted when used for multiple contaminants. Experience has demonstrated that an OSHA compliance officer may require quarterly monitoring of hood exhaust to demonstrate the effectiveness of the filtration in the given application and the corresponding protection of the workers occupying the space. These hoods are often misused.

21. Floor-mounted hoods are used when the vertical working space of a bench hood is inadequate for the work or apparatus to be contained in the hood. The base of the hood shall provide for the containment of spills by means of a base contiguous with the sidewalls, and a vertical lip of at least 1 in. (2.54 cm) or equivalent. The lip can be replaced by a ramp to allow wheeled carts to enter the hood. The hood must be furnished with distribution ductwork or interior baffles to provide uniform face velocity. Doors and panels on the lower portion shall be capable of being opened for the installation of apparatus.

ANSI Z9.5 2.3.5

N. Hoods — Face Velocities

The average air velocity face of a hood intended for standard use shall be 100 linear feet per minute (fpm) with a minimum of 70 fpm at any measured point. Maximum face velocity should not exceed 125 fpm. Designers may choose to design to 110 fpm, to allow for a margin of error in balancing.

8 CCR 5154.1(c)

AIHA Z9.5

Good Practice

O. Hoods — Sashes

1. Hoods shall have transparent movable sashes constructed of shatter-resistant, flame-resistant material that is compatible with the materials and processes to be used in the hood, and capable of being moved to close the entire front face.
2. Vertical-rising sashes are preferred. If three or more horizontally sliding sash panels are provided, the panels should be no more than 10 in. (25.4 cm) wide to allow them to serve as a safety shield narrow enough for a person to reach around to manipulate equipment. Multiple sashes may be installed within the same track.

ANSI Z9.5 3.1.1

Good Practice

Sashes may offer extra protection to lab workers since they can be positioned to act as a shield.

3. A force of five pounds shall be sufficient to move vertically and/or horizontally moving doors and sashes.

AIHA Z9.5 3.1.1

3. Laboratory Ventilation and Fume Hoods

Sticky sashes and doors are not moved, so they become useless. These specifications result from decades of experience.

4. Automatic sash closers with proximity sensors may be considered to allow for energy savings when the hood is not in operation. Note that a user's training program may be more effective in achieving this desirable end.

P. Hoods — Perchloric/Hot Acid Use

1. Where perchloric or other acids will be heated above ambient temperature, a dedicated acid hood shall be installed or provisions made to trap and scrub vapors at the point of emission, before they enter the laboratory ventilation system.

NFPA 45, Chapter 6-11.1

If perchloric acid is heated above ambient temperature, it will give off vapors that can condense and form explosive organometallic perchlorates. Limited quantities of perchloric acid vapor can be kept from condensing in laboratory exhaust systems by trapping or scrubbing the vapors at the point of origin. Nitric, hydrochloric, sulfuric, and other mineral acids are often used in digestion procedures at high temperatures.

2. Acid hoods and exhaust ductwork shall be constructed of materials that are acid-resistant, nonreactive, and impervious to the acid being used. No organic materials, including gaskets, shall be used in the hood construction unless they are known not to react with perchloric or other hot acids and/or their by-products;

ANSI Z9.5 3.2.4

NFPA 45, Chapter 6-11.2 and 6-11.5

Perchloric acid digestion may over time result in the condensation and consequential formation of metal perchlorate crystals, which can pose an explosion hazard, especially if combined with organic chemical condensate. Typically, 316 stainless steel or unplasticized PVC has been used. 316 stainless steel may not be appropriate for other hot acid applications, particularly hydrochloric acid. Consult with EH&S for guidance on the appropriate materials of construction of perchloric/hot acid digestion exhaust systems.

3. A water spray system shall be provided for washing down the hood interior behind the baffle and the entire exhaust system, including the stack and exhaust fan. It is not necessary to wash down the interior of the fume hood work area. The hood work surface shall be watertight with a minimum depression of 13 mm (1/2 in) at the front and sides. An integral trough shall be provided at the rear of the hood to collect wash-down water.

NFPA 45, Chapter 6-11.6

Perchloric/hot acid digestion hoods should be washed down after each use to minimize accumulations of potentially explosive perchlorate salts and other highly corrosive by-products.

4. Wash-down spray nozzles shall be installed in the ducts no more than 5 ft apart. The ductwork shall provide a positive drainage slope back into the hood. Ductwork

3. Laboratory Ventilation and Fume Hoods

shall consist of sealed sections, and no flexible connectors shall be used.

NFPA, Chapter 6-11.4

5. The hood baffle shall be removable for inspection and cleaning.

NFPA 45, Chapter 6-11.7

6. Ductwork for perchloric/hot acid hoods and exhaust systems shall take the shortest and straightest path to the outside of the building and shall not be manifolded with other exhaust systems. Preference shall be given to a routing that is as vertical as possible.

NFPA, Chapter 6-11.4

7. The exhaust fan shall be acid-resistant and spark-resistant. The exhaust fan motor shall not be located within the ductwork. Drive belts shall be conductive.

NFPA 45, Chapter 6-11.3

Q. Air Cleaning

1. Air-cleaning systems for laboratory exhaust systems, where required, shall be designed or specified by a responsible person to ensure that air-cleaning systems will meet the performance criteria necessary for regulatory compliance. See Chapter 14 of the *ASHRAE 1997 Handbook of Fundamentals*.
2. The flow rate through the filters shall be maintained at design specifications and shall not exceed the rated flow capacity of the filters.
3. Adsorption or other filtration media used for the collection or retention of gases and vapors shall be specified for a limited use. Specific hazardous materials to be collected, airflow rate, temperature, and other relevant physical properties of the system shall be incorporated into the selection of filtration media.
4. A reliable and adequately sensitive monitoring system shall be utilized to indicate adsorbent breakthrough, when such technology exists. The sensitivity of the monitoring system shall be a predetermined fraction of the Threshold Limit Value (TLV[®]) or appropriate alternative health standard of the contaminant being adsorbed, but shall not be more than 25% of the TLV[®]. The campus EH&S organization shall designate alternative health standards, if used.
5. The breakthrough time of the contaminant, before the effluent reaches no more than 50% of the TLV[®], shall be sufficient, based upon system capacity design to allow a work operation shutdown or switch-over to a parallel air cleaner, thus providing a fresh air cleaner.
6. For toxic gases and vapors, the filtration system shall be designed and sized for capacity to ensure adequate collection and retention for a worst-case scenario; when in the event of a spill or other major release, adequate warning is provided for personnel to stop work or enact other emergency procedures.
7. Exhaust streams conveying radioactive particulate materials shall be equipped with HEPA filters that meet DOE-STD-3020-2004 specifications if potential emissions of radioactive or highly toxic particulate chemical materials are deemed

3. Laboratory Ventilation and Fume Hoods

to present a hazard. The filters should be installed in bag-out housings meeting the requirements of Section HA of ASME AG-1 before being connected to a centralized exhaust system. These housings should be installed with built-in challenge aerosol injection ports as well as up- and downstream challenge aerosol sampling sections. Biological exhaust hoods shall be equipped with HEPA filters to remove all hazardous biological substances prior to connection to a centralized exhaust system. Biological Safety Cabinets use filters complying with NSF-49 and IEST-RP- CC001.3, Type C requirements, while additional building HEPA filters, if used, shall meet IEST-RP- CC001.3, Type E requirements.

8. HEPA filters shall be protected by prefilters to avoid the cost and hazards associated with frequent replacement.
9. HEPA filters shall be installed in a manner that allows for safely testing and replacing them. HEPA filters used to remove radioactive or highly toxic particulate chemical materials shall be installed in a manner that allows them to be quantitatively tested in accordance with Section TA of ASME AG-1 by means of a filter housing with built-in test sections, or designing the system in accordance with principles set forth in Section 5 of UCRL-AR-133354, Rev.2. Biological filters other than those installed in biological safety cabinets shall be installed so they can be tested in accordance with IEST-RP-CC034.1.

8 CCR for chemical and biological exposures

17 CCR for radiation exposures

ANSI Z9.5

DOE-STD-3020-97

ASME AG-1

NSF-49

Section 5.3.2.3 of ANSI Z9.5 requires that exhaust streams be “adequately filtered” for ducts conveying radioactive or biological materials before entering a combined system. Highly hazardous aerosols are customarily removed by HEPA filters. References to HEPA filter standards are given to implement this requirement of ANSI Z9.5. HEPA filters need to meet established standards and be placed in housings or systems that allow for reproducible and quantitative leak testing in accordance with recognized standards. HEPA filters for radioactive material service are often replaced using “bag-in/bag-out” methods, while biological filters are customarily vapor-sterilized before replacement. The quantitative testability requirements do not apply if there are additional HEPA filters downstream of these filters, but do apply to the last filter or pair of filters in any ventilation system equipped with HEPA filters used to protect workers, the public, or the environment.

R. Specialty, Controlled Climate, and Cold Rooms

1. The local EH&S organization shall be consulted to review and approve arrangements for providing fresh and exhaust air during periods of occupancy of cold rooms.
2. Specialty rooms, designed for human occupancy, shall have latches that can be operated from the inside to allow for escape.

3. Laboratory Ventilation and Fume Hoods

3. Latches and frames shall be designed to allow actuation under all design conditions, such as freezing. Magnetic latches are recommended.
4. Doors of walk-in specialty rooms shall have viewing windows and external light switches.

S. Hoods — Commissioning and Performance Testing

1. A written commissioning plan shall accompany design documents and be approved by the commissioning authority in advance of construction activities. The commissioning plan, along with the other project documents, shall be available to all potential suppliers and contractors prior to bid. The commissioning plan shall address the operation of the entire ventilation system where the hoods, laboratories, and associated exhaust and air supply ventilation systems are considered subsystems. The plan shall include, in addition to written procedures to verify or validate the proper operation of all system components:
 - Laboratory Chemical Hood Specification and Performance Tests
 - Preoccupancy Hood and Ventilation System Commissioning Tests
 - Preoccupancy Laboratory Commissioning Tests

ANSI Z9.5 6.2.2

ANSI/ASHRAE 110 1995

2. Preliminary and final commissioning documents shall be issued to the appropriate parties by the University representative. The documents shall include:
 - Design Flow Specifications
 - Laboratory and System Drawings for Final System Design
 - Copy of Test and Balance Report
 - Commissioning Test Data
 - List of Ventilation System Deficiencies uncovered and the details of how (and if) they were satisfactorily resolved

Operational deficiencies and other problems uncovered by the commissioning process shall be communicated to the responsible party (i.e., installer, subcontractor, etc.) for prompt correction.

ANSI Z9.5 6.2.3

3. The volumetric flow exhausted from a laboratory chemical hood shall be determined by measuring the flow in the exhaust duct, using industry-approved methods.

ANSI Z9.5 6.3.1

4. The hood static pressure shall be measured above the outlet collar of the hood at the flows required to achieve the design average face velocity.

ANSI Z9.5 6.3.2

5. The average face velocity, cross draft, response time, smoke containment, and tracer gas containment shall be determined by the methods described in the *ANSI/ASHRAE 110-1995 Method of Testing Performance of Laboratory Fume*

3. Laboratory Ventilation and Fume Hoods

Hoods. The area Industrial Hygienist shall approve the results of the fume hood commissioning tests.

4. EMERGENCY EYEWASH AND SAFETY SHOWER EQUIPMENT

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A. Scope

This guide presents criteria for eyewash and shower equipment for the emergency treatment of the eyes or body of a person who has been exposed to chemicals. The following types of equipment are covered: eyewash equipment, safety showers, combination shower and eyewash or eye/face-wash equipment, and drench hoses. Minimum regulatory requirements for emergency eyewash and shower equipment are outlined in 29 CFR 1910.151 (Federal) and 8 CCR 5162 (California). Specific application, installation, and operation decisions are best determined through consultation with EH&S.

B. Applications

1. Where the eyes or body of any person may be exposed to injurious or corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use. These situations include:
 - Areas where corrosive or injurious chemicals are used, such as:
 - Solutions of inorganic or organic acids or bases with a pH of 2.0 or less, or 12.5 or more;
 - Other organic or inorganic materials that are corrosive or irritating to eyes or skin (e.g., methylene chloride, phenol); or
 - Organic or inorganic materials that are significantly toxic by skin absorption (e.g., phenol, hydrazine).
 - Areas where corrosive chemicals are used in a closed system that can catastrophically fail and cause the chemicals to leak (i.e., liquid lead-acid battery-charging areas, or areas where pressurized systems with corrosive liquids are used);
 - Storage areas where breakable containers of injurious or corrosive materials (≥ 2.5 liters or ~ 0.6 gal) are handled outside their original shipping cartons;
 - Waste accumulation areas that contain corrosive waste materials;
 - Areas where operations involve the use of air or water reactive liquids or solids;

4. Emergency Eyewash and Safety Shower Equipment

- All open tray film-processing work areas using chemical developers and fixers; and
- Acid washing work areas.

29 CFR 1910.151(c)

8 CCR 5162

8 CCR 5217

22 CCR 66261.22

Good Practice

2. An emergency shower shall be provided at all work areas where, during normal operations or foreseeable emergencies, areas of the body may come into contact with a substance that is corrosive, severely irritating to the skin, or toxic by skin absorption. An emergency shower shall be provided at all work areas where formaldehyde solutions in concentrations greater than or equal to 1% are handled.

8 CCR 5162(b)

8 CCR 5217(i)(2)

3. A plumbed eyewash shall be provided for all work areas where, during normal operations or foreseeable emergencies, the eyes of an employee may come into contact with a substance that can cause corrosion, severe irritation, or permanent tissue damage, or is toxic by absorption. A plumbed eyewash shall be provided at all work areas where formaldehyde solutions in concentrations greater than or equal to 0.1% are handled.

8 CCR 5162(a)

8 CCR 5217(i)(3)

4. When chemicals are used in small quantities and the likelihood of exposure is limited, only an eyewash may be required. When the quantities are larger and significant splashing or spraying may occur, a safety shower shall also be required. The area Industrial Hygienist shall make this determination.

8 CCR 5162(a)

8 CCR 5217(i)(3)

5. Generally, eyewashes are not required in areas where:

- Chemicals are stored in quantities less than 8 ounces (~240 mL) and used at room temperature at a rate of less than 2 ounces (~60 mL) per day. (Note: perchloric acid, hydrofluoric acid, formaldehyde concentrations ≥ 0.1 %, and the alkali metals and alkali metal compounds are not covered by this exemption.)
- Compounds hazardous to the eye or skin are used in sealed systems at or below atmospheric pressure, and catastrophic failure or leakage is unlikely. However, an eyewash or shower may be appropriate if the system is filled, topped-off, or drained in other than a totally enclosed manner.
- Materials hazardous to the eye or skin are stored in bulk in metal or plastic containers, and are not decanted.

C. Equipment Requirements

1. Emergency eyewash, safety shower, and combination units shall comply with the requirements of ANSI Z358.1.
2. The eyewash should have a plumbed drain to the sanitary sewer connection. When a sewer connection cannot be provided, a means shall be provided to empty test water into a bucket that can hold at least 10 gallons.

8 CCR 5162(e)

The 10-gallon capacity criterion comes from flowing water for 15 minutes at a flow rate of 0.4 gallons per minute. Eyewash fountains shall be plumbed with a drain to promote the flushing of the eyewash, decrease the buildup of microbial contamination, and reduce the risks associated with a wet floor. All drains should have an appropriate trap to prevent sewer gases from entering the building.

3. Eyewash and safety shower water should be delivered at a tepid temperature. For indoor systems, typical cold water supply temperature is considered satisfactory. If the heating of hot water is required to provide tepid water, then a mixing valve to blend hot and cold water shall be provided.

ANSI Z358.1 Appendix B6

Outdoor plumbing needs to be protected from the sun and freezing. The requirement to deliver tepid water means that faucet-mounted eyewashes are not acceptable, because the water will emerge at the temperature of the tap water, which could range from ice cold to scalding hot. Tanks holding tepid water shall be avoided because of the risk of *Legionella* proliferation.

4. The water supply to safety showers and combination units shall be controlled by a ball-type shutoff valve that is visible, well marked, and accessible to shower testing personnel in the event of leaking or failed shower head valves. The valve should not be located where an unauthorized person could easily shut it off.

Good Practice

5. The area around the safety shower should be painted a bright color and should be well lighted. Whenever possible, the floor immediately beneath the eyewash and emergency shower, and to a radius of 30 inches, should be constructed of a nonslip surface and be a distinctive pattern and color to facilitate promoting a clear path of access.

Good Practice

D. General Location

1. Emergency eyewash facilities and safety showers shall be in unobstructed and accessible locations that require no more than 10 seconds for the injured person to reach along an unobstructed pathway. If both eyewash and shower are needed, they shall be located so that each can be used at the same time by one person.

A travel distance of 55 feet in 10 seconds is cited by ANSI as the distance covered

4. Emergency Eyewash and Safety Shower Equipment

by an individual walking at a normal pace. Consideration should be given to the impaired abilities of the injured victim and the availability of others in the immediate area to assist. There should be no doors in the path of travel; however, if there are doors, there should be no more than one, and it shall swing in the direction of travel.

8 CCR 5162(c)

ANSI Z358.1 Appendix B5

Prudent Practices in the Laboratory, Section 6.F.2.5

2. An emergency eyewash and safety shower station should be located as near as practicable to laboratory fume hoods designed for handicapped access.

Good Practice (Derived from communication with the Office of the State Architect)

3. No obstructions, protrusions, or sharp objects shall be located within 16 inches from the center of the spray pattern of the emergency shower facility (i.e., a 32-inch clearance zone).

8 CCR 5162(c)

ANSI Z358.1 4.5.7 (3)

4. No electrical apparatus, telephones, thermostats, or power outlets should be located within 18 inches of either side of the emergency shower or emergency eyewash facility (i.e., a 36-inch clearance zone) or within any area that may be reasonably considered as a splash or flood zone. If 120-volt outlets or receptacles are present within 6 feet of an eyewash or shower, it shall be equipped with a Ground Fault Circuit Interrupter (GFCI).

NFPA 70 (NEC)

Good Practice

5. Opaque modesty curtains, which can be drawn around safety showers, may be provided.

Good Practice

Personnel shall remove contaminated clothing while using a safety shower; if not, the corrosive/toxic material in the clothing will continue to act. Removing contaminated clothing without using a safety shower has caused skin burns after the original splashed chemical had been removed. Employees will resist removing contaminated clothing if they are in visible areas, so opaque modesty screens are needed. The screen can be stowed in a folded condition and deployed as needed, just like any shower curtain.

E. Pre-Commissioning Testing

Proper installation and operation of the equipment, within the specifications of the ANSI Z358.1 standard and the requirements of this section, shall be demonstrated prior to project closeout and facility occupation. Tags to allow periodic testing records to be kept shall be affixed to the showers and eyewash fountains. A commissioning checklist such as that included in Appendix 4-1 should be used to document proper equipment installation and operation.

Prudent Practices in the Laboratory, Section 6.F.2.6

4. Emergency Eyewash and Safety Shower Equipment

*ANSI Z358.1 5.5.1
8 CCR 5162 (e)*

F. Approved Equipment

All emergency eyewash and safety shower equipment shall meet the requirements of 8 CCR 5162 and ANSI Z358.1.

The most versatile and complete emergency rinsing facility would include a combination unit with an emergency eye/face wash, a safety shower, and a drench hose.⁷ See Appendix 4-2 for an illustration of an emergency eyewash safety shower combination unit, installed within the heights listed.

*8 CCR 5162
29 CFR 1910.151(c)
OSHA interpretation letter dated 09/30/94
ANSI Z358.1*

⁷ A drench hose may not be used in lieu of plumbed eyewash equipment, but may be used as a supplement.

Appendix 4-1. Emergency Eyewash Safety Shower Commissioning Checklist

Inspector name:	Date (mm/dd/yy):
Equipment ID number:	

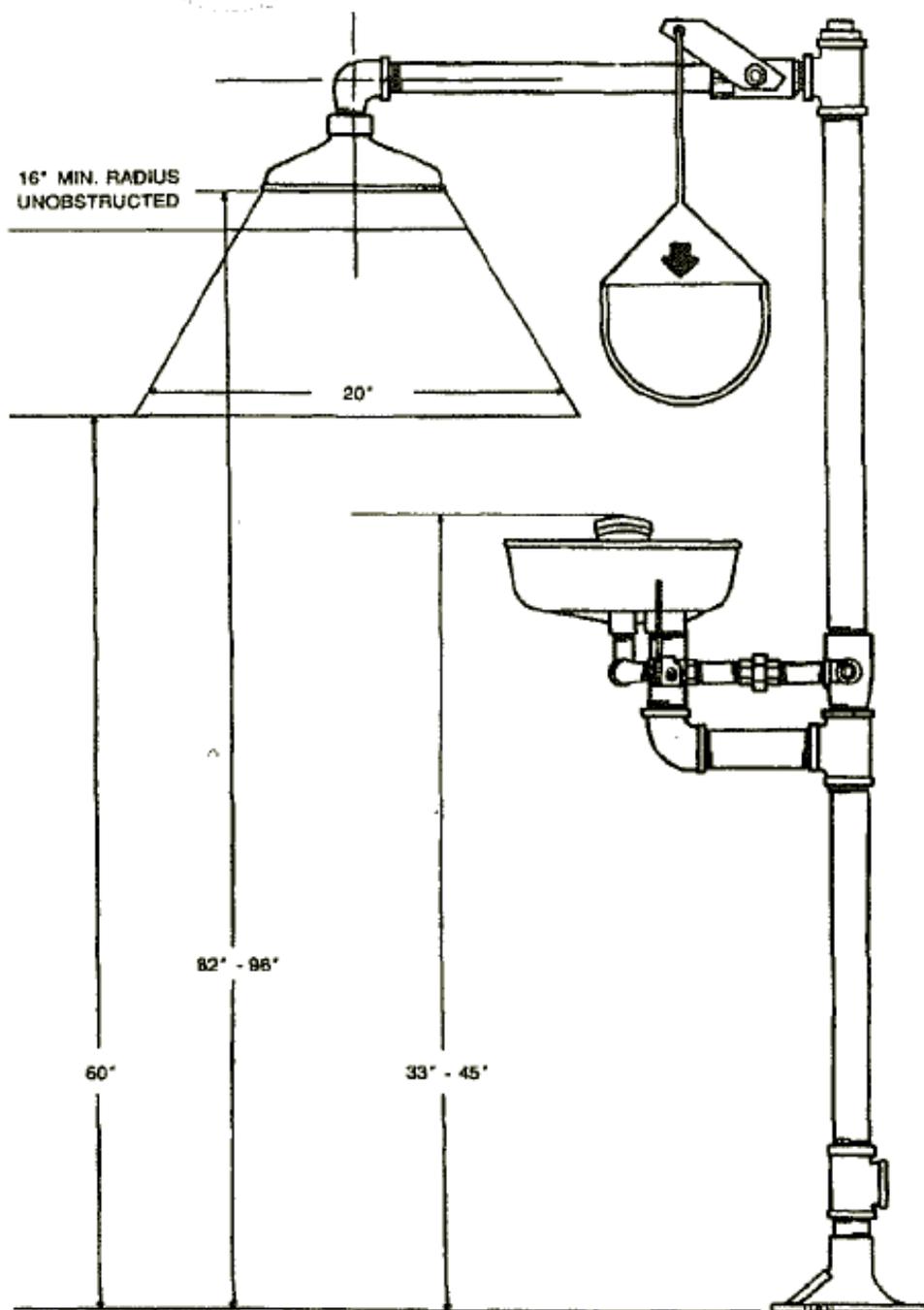
Criteria	Response	Comment / Corrective Action
Highly visible sign	yes / no	
Supply lines insulated (outside locations)	yes / no	
Supply lines have anti-freeze / scald valves (outside locations)	yes / no	
EE/SS supply valve protected from shut off	yes / no	
EE nozzles have covers in good condition	yes / no	
EE nozzles free of debris and contamination	yes / no	
EE nozzles aligned	yes / no	
EE/SS footprint demarcated	yes / no	
Outlets/switches guarded if closer than 3'	yes / no	
Panels/disconnects at least 36" from EE/SS	yes / no	
EE clearance from wall/pole 6" minimum	yes / no	measurement =
EE clearance on right/left side 18" minimum	yes / no	measurement =
EE front clearance 32" minimum	yes / no	measurement =
EE height 33-45" @ nozzle	yes / no	measurement =
SS clearance radius of 16"	yes / no	measurement =
SS height 82-96" @ head	yes / no	measurement =
SS handle height 69" maximum	yes / no	measurement =
EE/SS located in same vertical plane	yes / no	
EE pressure forces off nozzle covers	yes / no	
EE dispersion: stream fills inner ovals of template	yes / no	
EE dispersion: streams approximately equal height	yes / no	
EE paddle stays open during operation	yes / no	
SS handle remains open during operation	yes / no	
Flows (individual operation): EE: 0.4, EFW: 3.0, SS 20 GPM	yes / no	
Flows (simultaneous operation): EE: 0.4, EFW: 3.0, SS 20 GPM	yes / no	
EE/SS visual water assessment		clear / cloudy / rusty

EE = emergency eye wash

EFW = emergency face wash

SS = safety shower

Appendix 4-2. Combination Emergency Eyewash Safety Shower Illustration



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5. PRESSURE VESSEL COMPONENTS AND SYSTEMS AND COMPRESSED GAS CYLINDERS

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I. Design of Pressure Vessels and Systems.....	5-7

A. Scope

This section applies to all research laboratory facilities, including leased properties. It covers all unfired pressure systems including vessels (i.e., storage tanks; compressed gas cylinders, cryogenic dewars) that have been designed to operate at pressures above 15 psig. This does not cover fired pressure vessels or utilities (i.e., boilers, “house air”) inspected and maintained by Physical Plant, nor does it apply to medical patient-care facilities and medical gas systems. (NFPA-99 “Health Care Facilities” may be consulted for guidance on pressure systems, but this standard does not apply to research laboratories.)

B. Compressed Gas Cylinder Storage

1. Cylinders of compressed gases shall be stored in areas where they are protected from external heat sources such as flame impingement, intense radiant heat, electric arc, or high-temperature steam lines.
8 CCR 4650(a)
2. Inside of buildings, cylinders shall be stored in a well-protected, well-ventilated, dry location, and flammable gas cylinders shall be at least 20 feet from highly combustible materials.
8 CCR 4650(b)
CGA P-1 3.7 & 4.2.2
3. The heating of flammable gas storage areas shall be indirectly heated, such as by air, steam, hot water, etc.
Good Practice
4. Cylinders shall not be kept in unventilated enclosures such as lockers and cupboards.
8 CCR 4650(c)
5. Adequate space shall be made available for the segregation of gases by hazard class. Flammable gases shall not be stored with oxidizing agents. Separate

5. Pressure Vessel Components and Systems and Compressed Gas Cylinders

storage for full or empty cylinders is preferred. Such enclosures shall serve no other purpose.

6. Cylinders containing strong oxidizers, such as oxygen, nitrous oxide, etc., shall not be stored near flammable gases or other combustible materials. Oxidizing gases shall be stored at a minimum distance of 20 feet from highly combustible materials, or a noncombustible barrier that is at least 5 feet high and fire-resistant. Valves, pipe fittings, regulators, and other equipment shall be constructed of material and pressure rating that is also compatible with oxygen. Code requires that only noncombustible barriers be used.

8 CCR 4650(d)

CGA P-1 3.7.2

24 CCR 9 (CFC), Section 8001.11.8

7. Liquefied fuel-gas cylinders shall be stored/transported in an upright position so that the safety relief device is in direct contact with the vapor space in the cylinder at all times.

8 CCR 4650(e)

8. When toxic or highly toxic flammable gases are stored in rooms outside of gas cabinets or exhausted enclosures, the storage rooms shall be provided with explosion control.

24 CCR 9 (CFC), Section 8003.1.7

Required for H-6 occupancies, but good practice for other situations.

9. When separate gas storage rooms are provided, they shall operate at a negative pressure in relation to the surrounding area, and direct the exhaust ventilation to the fume exhaust system, assuring that incompatible gases are not mixed in the ductwork.

24 CCR 9, Section 8003.3.1.3.4

Required for H-6 occupancies, but good practice for other situations.

10. Storage areas shall be secured against unauthorized entry.

24 CCR 9 (CFC), Section 7401.6.1

Required for H-6 occupancies, but good practice for other situations.

11. The storage of compressed gas cylinders shall not obstruct exits or routes of egress. Also, compressed gas cylinders shall not be stored near elevators, walkways, platform edges, or in locations where heavy moving objects may strike or fall upon them.

CGA P-1 3.7.2, & 3.7.3

24 CCR, Part 2, Title 19

12. Emergency power shall be provided for exhaust ventilation, gas-detection systems, emergency alarm systems, and temperature control systems.

24 CCR 9 (CFC), Section 8003.3.1.4

Required for H-6 occupancies, but good practice for other situations.

C. Compressed Gas Cylinder Restraint

1. Approved storage racks (e.g., Unistrut, pipe racks) shall be provided that adequately secure gas cylinders by chains, metal straps, or other approved materials, to prevent cylinders from falling or being knocked over. Chains are preferable to straps. Straps shall be noncombustible.

8 CCR 4650 (e)

24 CCR 9, Section 7401.6.4

NFPA 45, 8-1.5

2. Cylinder restraints shall be sufficient to prevent the cylinder from tipping over. In seismically active areas, more than one chain/strap should be used (double chains/straps should be located at one-third and two-thirds the height of the cylinder).

8 CCR 4650

Prudent Practices in the Laboratory, Section 4.E.4

Good Practice

3. Chain/strap restraints shall be used to restrain a maximum of 3 cylinders per chain/strap or per set of chains/straps (if double-chained/strapped).

Good Practice

4. The purchase and installation of compressed gas cylinder securing systems shall be subject to review and approval of EH&S.

5. Gas cylinder securing systems should be anchored to a permanent building member or fixture. Connection to a permanent building member or fixture is needed to prevent movement during a seismic event.

Good Practice

D. Toxic and Corrosive Gas Storage and Distribution

Treatment systems shall be reviewed and approved by EH&S and shall comply with applicable local environmental regulations. Gas storage cabinets and distribution systems should comply with the following standards:

- Semiconductor Equipment and Materials International, *Guide for Secondary Containment of Hazardous Gas Piping Systems*, Standard F6-1992 (1992)
- Semiconductor Equipment and Materials International, *Guide for Gas Source Control Equipment*, Standard F13-1993 (1993)
- Semiconductor Equipment and Materials International, Reapproval of F14-93, *Guide for the Design of Gas Source Equipment Enclosures Facilities Standards and Safety Guidelines*, F14-93
- Semiconductor Equipment and Materials International, *Guide for Gaseous Effluent Handling*, F5-90

Good Practice

E. Requirements for Gas Cabinets

1. Storage and use of toxic and highly toxic compressed gas cylinders shall be within

5. Pressure Vessel Components and Systems and Compressed Gas Cylinders

exhaust ventilated gas storage cabinets, laboratory fume hoods, exhausted enclosures, or within separate ventilated gas storage rooms without other occupancy or use. It is acceptable to mount lecture bottles connected to a manifold in a fume hood.

24 CCR 9, Section 8003.3.1.3.1

Required for H-6 occupancies, but good practice for other situations.

2. Gas cabinets shall be located in a room or area that has non-recirculated exhaust ventilation and operates at negative pressure in relation to the surrounding area, and shall be connected to the fume exhaust system.
3. Gas cabinets shall have self-closing limited access ports or noncombustible windows to provide access to equipment controls, with an average face velocity of at least 200 fpm, and a minimum of 150 fpm at any part of the access port or window, and design criterion of 200 fpm at the cylinder neck when the average face velocity is >200 fpm.
4. Gas cabinets shall have self-closing doors, be constructed of at least 0.097-inch (12 gauge) steel, have internal sprinklers, and be seismically anchored.
5. Gas cabinets shall be fitted with sensors connected to alarms to notify personnel in the event of a leak or exhaust system failure as appropriate.

*Standards and explanatory note applicable to Items 3 through 5:
24 CCR 9, Sections 8003.3.1.3.1, 8003.3.1.3.2, and 8003.3.3.1.8*

Required for H-6 occupancies, but good practice for other situations. For planning purposes, a gas cabinet shall contain not more than 3 cylinders, except where cylinder contents are 1 pound net or less, in which case gas cabinets may contain up to 100 cylinders. It has already been specified that gas cabinets shall comply with semiconductor industry standards.

F. Monitoring Toxic and Highly Toxic Gases

1. Whenever the quantities and composition of the expected toxic gas inventory levels are exceeded, as interpreted by EH&S, then a continuous gas detection system shall be provided to detect the presence of gas. This system shall detect at or below the permissible exposure limit, ceiling limit, or maximum permissible concentration, except for toxic gases where EH&S has determined that the physiological warning properties for the gas are sufficiently below the permissible exposure limit. The detection system shall initiate a local alarm and transmit a signal to a constantly attended location. Activation of the monitoring system shall automatically close the shutoff valve on toxic, highly toxic, and radioactive gas supply lines to the system being monitored.
24 CCR 9 (CFC), Sections 8003.3.1.6 and 8003.3.1.7
2. A provision shall be made to allow the air monitoring equipment to function alarms and shut off gas flows as close to the gas sources as possible. Guidance about the gases to be monitored, alarm set points, and where and how the alarms sound shall be provided by the campus EH&S organization.

5. Pressure Vessel Components and Systems and Compressed Gas Cylinders

3. An approved supervised smoke detection system shall be provided in rooms or areas where highly toxic compressed gases are stored indoors.

24 CCR 9 (CFC), Section 8003.3.1.7

G. Silane

1. Silane is not highly toxic, but it is pyrophoric. Leaking silane does not always ignite instantly, which allows pockets of flammable mixtures to accumulate before ignition. The ensuing deflagration can cause severe damage. Silane storage falls into two categories: indoor bunker or outdoor nest.
2. Silane cylinders shall be stored while secured to steel frames in a silane nest or bunker that is external to buildings that are open on three sides and enclosed by a roof; the cylinders shall be secured by means of an open chain link fence. A canopy provided to protect the stored cylinders from the elements shall be ≥ 12 ft above grade. The nest shall be ≥ 9 ft from buildings and the fence. A three-sided fence with the fourth wall constituted by a building wall is acceptable. Bunkers shall be approved by the authority having jurisdiction.

NFPA 318, Chapters 6-4.1, 4.1.1, 4.1.2, 5.1.1, 5.1.2, 5.3

The objective is to provide ample ventilation and minimize potential blast/fire damage in the event of a leak and deflagration.

3. Cylinders in silane-dispensing stations shall be separated by means of a 1/4-inch steel plate extending 3 inches beyond the footprint of the cylinder and from the top of a purge panel, to 12 inches below the cylinder valve.

NFPA 318 Chapter 6-4.3 (b)

These specifications reduce the chance of having a deflagration or fire and minimize damage and injuries should such an incident occur.

4. Mechanical or natural ventilation shall provide 1 cfm/ft² of storing or dispensing area. Mechanical ventilation, if used, shall be furnished with emergency backup power.

NFPA 318 Chapter 6-4.3 (c)

These specifications reduce the chance of having a deflagration or fire and minimize damage and injuries should such an incident occur.

5. Automatic water deluge water spray protection shall be provided in dispensing areas directed at individual cylinders activated by UV/IR detectors. Detection will also activate automatic shutoff valves.

Good Practice

These specifications reduce the chance of having a deflagration or fire and minimize damage and injuries should such an incident occur.

6. Remote manual shutoff that can be operated from at least 15 feet from the dispensing area shall be provided.

NFPA 318 Chapter 6-4.3 (e)

5. Pressure Vessel Components and Systems and Compressed Gas Cylinders

These specifications reduce the chance of having a deflagration or fire and minimize damage and injuries should such an incident occur.

7. Silane-dispensing areas shall be separated from buildings and fences

NFPA 318 Chapter 6-4.3 (a), 5.3 (a)

These specifications reduce the chance of having a deflagration or fire and minimize damage and injuries should such an incident occur.

8. An automated sequential inert gas evacuation/purge shall be provided for silane-dispensing equipment. The inert gas is introduced upstream of the first vent or exhaust connection of a gas delivery header.

NFPA 318 Chapter 6-4.3 (g)

These specifications reduce the chance of having a deflagration or fire and minimize damage and injuries should such an incident occur.

9. Gas cabinets, if used, shall have only enough room for one cylinder and meet the specifications of SEMI F14-93.

NFPA 318 Chapter 6-5.1.3

These specifications reduce the chance of having a deflagration or fire and minimize damage and injuries should such an incident occur.

10. An automated sequential inert gas evacuation/purge shall be provided in the gas cabinet with the inert gas introduced upstream of the first vent or exhaust connection of a gas delivery header.

NFPA 318 Chapter 6-7.2

11. Remote manual shutdown shall be provided from the outside of the gas cabinet.

Good Practice

Note for items 10 and 11, above: NFPA 318 does not mandate compliance with a SEMI standard, but all other parts are taken from NFPA 318 and are meant to reduce the chance of having a deflagration or fire, and to minimize damage and injuries should such an incident occur. The SEMI standard is cited to ensure that the equipment meets an adequate, generally recognized standard of quality.

H. Design of Systems and Apparatus for Cryogenic Fluids.

1. The position of valves and switches for emergency shutdowns shall be accessible and clearly labeled.

Good Practice

2. Nonsulated pipes or vessels should be positioned and/or identified to prevent inadvertent contact with an unprotected part of the body.

Good Practice

3. Critical vent areas should be covered, or pointed down (i.e., Dewar necks, and pressure reliefs).

Good Practice

5. Pressure Vessel Components and Systems and Compressed Gas Cylinders

4. All portions of lines that could contain liquid cryogen shall be protected by pressure relief devices. This means that a pressure relief device shall be installed on any portion of a line that could be isolated by shutoff valves.

Good Practice

I. Design of Pressure Vessels and Systems.

Normal and emergency relief venting and vent piping for pressure vessels should be adequate and in accordance with the design of the vessel.

*ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels.
8 CCR Chapter 4, Subchapter 1*

6. HAZARDOUS MATERIALS STORAGE CABINETS

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C. Design.....	6-1
D. Venting Hazardous Material Storage Cabinets.....	6-2
E. General Installation Requirements.....	6-3

A. Scope

This section applies to all campus facilities, including leased properties. It covers the design, construction, and installation of hazardous materials storage cabinets (including flammable liquid, corrosive material, and toxic material storage cabinets). Gas cabinet information is in Chapter 5.

B. Approvals and Listings

1. The purchase and installation of storage cabinets for both flammable liquids and toxic materials shall be subject to review and approval of EH&S.
2. Flammable liquid storage cabinets shall be listed by a Nationally Recognized Testing Laboratory such as Underwriters Laboratories or Factory Mutual, or State Fire Marshal.

Good Practice

NRTL listing or EH&S approval assures a minimum level of quality consistent with Code requirements and good practice. "UL Listing" is not required for corrosive or toxic material storage cabinets.

C. Design

1. Laboratories that store, use, or handle more than 10 gallons of flammable or combustible liquids shall have one or more flammable liquid storage cabinets.
24 CCR 9 (CFC), 7903.2.1.6
2. Flammable liquid storage cabinets shall not store in excess of 60 gallons of Class I flammable or Class II combustible liquids.
24 CCR 9 (CFC), 7902.5.9.2
NFPA 30, Chapter 4-3.1
3. Flammable liquid storage cabinets shall be conspicuously labeled with the warning "FLAMMABLE — KEEP FIRE AWAY" in red letters on a contrasting background. Doors shall be well fitted, self closing and equipped with a self-latching device.
8 CCR 5533
NFPA 30, Chapter 4-3.5
24 CCR 9 (CFC), 8001.10.6.2
4. When flammable or combustible liquids present multiple hazards, the storage requirements for each hazard shall be addressed.

6. Hazardous Materials Storage Cabinets

24 CCR, 7902.5 et seq

For example, acetic acid is a corrosive and combustible material. Therefore, if it is stored in a flammable cabinet with other flammable materials, it shall be segregated (i.e., secondary containment).

5. Laboratories that store, use, or handle more than 10 pounds of highly toxic liquids or solids shall have one or more approved and vented toxic material storage cabinet.

24 CCR 9 (CFC), Sections 8003.1, 8003.3.1.3.2, 8003.3.1.3.1 8003.3.1.3.5, 8003.12, et seq, 8001.15.2.3.1 (note exception), and 8001.10.6.2; Table 8001.15-A-D, 8001.10.6 24 CCR 2 (CBC) Chapter 3, Tables 3-E and 3-I

6. Where necessary, vented cabinets should be provided to store toxic materials, separated by hazard class. The vents shall be connected, preferably at the top of the cabinet to a supply ventilation system and the bottom of the cabinet to an exhaust ventilation system in accordance with the provisions of Section D of this chapter. Interior balance of the cabinet should be neutral to the outside. The cabinets should be compatible with the materials being stored.

*Prudent Practices in the Laboratory, Section 3.C and 5.D
Good Practice*

7. Corrosive/toxic material storage cabinet shelving shall be constructed to prevent spillage of contents with tight-fitting joints, a welded or riveted liquid-tight bottom, a door sill of at least 2 inches, and lockable cabinet doors that are self-closing and self-latching. Corrosive materials should not be stored in metal cabinets unless the materials of construction are specifically treated to be corrosion-resistant.

Prudent Practices in the Laboratory, Section 3.C and 4.E

D. Venting Hazardous Material Storage Cabinets

1. Venting of storage cabinets is not required by Code and has not been demonstrated to be necessary for fire protection purposes. Additionally, if improperly performed, venting of a storage cabinet could compromise the ability of the cabinet to adequately protect its contents from involvement in a fire. However, there may be other health and safety considerations (e.g., odor control, control of potentially hazardous vapors) that dictate that the interior of a cabinet be ventilated. Early in the design phase, the designer shall discuss ventilation of hazardous material storage cabinets with Facilities Management, Environmental Health and Safety, and the Fire Marshal.
2. If a flammable liquid storage cabinet is ventilated, then it shall be connected through the lower bung opening to an exterior exhaust in such a manner that it will not compromise the specified performance of the cabinet. The other metal bung shall be connected to an air supply located outside of the fire control area.
3. If the cabinet is not vented, then it shall be sealed with the bungs supplied or specified by the manufacturer.

*24 CCR 9 (CFC), Section 7901.11.1.1
Good Practice*

6. Hazardous Materials Storage Cabinets

4. Toxic material storage cabinets, when used to store Highly Toxic materials in excess of an exempt amount shall be vented in a manner like flammable liquid storage cabinets.

24 CCR 9 (CFC), Section 8003.3.1.3.3

5. Exhaust vent materials for hazardous material cabinets shall be compatible with contents of the cabinets. Vent materials for flammable liquid storage cabinets shall be resistant to high temperatures generated in a fire. Stainless steel, hard-soldered copper, and carbon steel are appropriate vent materials for flammable storage cabinets, provided the material is compatible with the intended service. Nonmetallic duct shall not be used to vent flammable storage cabinets. Compatible nonmetallic duct material, such as PVC, can be used for toxic material storage cabinet service. Polypropylene, which is combustible, is not appropriate vent duct material.

24 CCR 9 (CFC), Section 7901.11.1.1

The citation does not specifically authorize or forbid venting flammable storage cabinets. The citation states the following requirement: "Piping, valves, fittings, and related components intended for use with flammable and combustible liquids shall be designed and fabricated from suitable materials having adequate strength and durability to withstand the pressures, structural stresses, and exposures to which they could be subjected. Such equipment shall be in accordance with nationally recognized engineering standards, be listed for the application or be approved...."

E. General Installation Requirements

1. Flammable liquid storage cabinets shall NOT be located near exit doorways, stairways, or in a location that would impede leaving the area.
2. Flammable liquid storage cabinets shall NOT be wall mounted.

Good Practice

Wall-mounted cabinets are not UL Listed or FM Approved. The mounting could breach the fire-resistive integrity of the cabinet.

3. Flammable liquid storage cabinets shall NOT be located near an open flame or other ignition source.

Good Practice

An open flame or other ignition source could start a fire or cause an explosion if an accident or natural disaster brought the ignition source and flammable liquids or vapors together.

4. One room shall not contain more than three flammable liquid storage cabinets unless those groups of three cabinets are separated from each other by a distance of not less than 100 feet (30 m) – OR – if the building is protected by an automatic sprinkler system, the number of cabinets in any one group shall be increased to six.

8 CCR 5533

NFPA 30, Chapter 4-3.2

5. Flammable and toxic/corrosive liquid storage cabinets shall be seismically anchored to prevent spillage of contents. Anchoring must not compromise the

6. Hazardous Materials Storage Cabinets

integrity of the fire rating, i.e., drilling holes through a free-standing cabinet.
Prudent Practices in the Laboratory, Sections 4.E.1 and 4.E.2

7. BIOSAFETY LABORATORIES

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A. Introduction

Containment is defined as a safe method for managing hazardous materials or infectious agents in an environment where they are handled or maintained. The purpose of containment is to reduce or eliminate the exposure of hazardous materials or infectious agents to laboratory workers, other persons, and the environment.

Containment is divided into three levels: primary, secondary, and tertiary. Primary containment involves standard work practices to protect personnel and the immediate work area; secondary containment is the protection of the environment outside of the work area; and tertiary containment involves the use of highly specific biological barriers that prevent the survival of an organism outside of the host. The three main components of containment include work practices, safety equipment, and facility design. The guidelines listed here are for facility design and safety equipment used in the containment of infectious agents.

In recent years, laboratory designers and architects have constructed open laboratories instead of the more traditional closed laboratory. Regardless of an open or closed design, there are a number of factors that should be considered before construction activities begin. These factors include, but are not limited to, the placement of HVAC systems, acoustic considerations, plumbing for sanitary drainage, laboratory drainage and vent systems, water supply systems, lighting, windows, access control and security, biological safety cabinets and fume hoods, storage, compressed gas systems, fire protection systems, and power for standard and emergency uses.

Before a proposed biosafety containment laboratory can be effectively planned, a risk assessment is needed to determine the containment conditions that will be required to mitigate the hazards associated with the proposed work. Risk assessments, conducted on a case-by-case basis, should consider factors such as the types of biohazardous materials, the nature of the proposed work, laboratory and safety equipment needs, regulatory requirements, and the requirements of the University.

B. Scope

The guidelines presented below are for general laboratory use for Biosafety Levels (BSL) 1, 2, and 3 (as defined by CDC/NIH) for biological research laboratories. The campus Institutional Biosafety Committee sets biosafety levels for research projects in accordance with the latest version of the *NIH Guidelines for Research Involving*

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Recombinant DNA Molecules. These design guidelines do not factor in American with Disabilities Act (ADA) issues, nor recent changes to building or fire codes. If modifications are required due to any of these changes, biosafety considerations will be adjusted.

The Institutional Biosafety Officer must be involved in design review and approval for new or modified BSL-1, BSL-2, and BSL-3 laboratories, as described in this chapter.

Since additional containment requirements may be imposed when working with specific agents, these design guidelines do not apply to the following:

- Biocontainment facilities for animals
- Biocontainment facilities for plants
- Insectaries for disease vectors
- Biocontainment facilities for select agents
- Biocontainment facilities for U.S. Department of Agriculture–regulated animal and plant pathogens
- Biocontainment facilities for large-scale (≥ 10 liters in a single vessel) biological work
- Biological work in clean rooms, or biological work covered by the Food and Drug Administration
- Biosafety Level-4 facilities

C. Basic Laboratory Design for Biosafety Levels 1 and 2 Laboratories

For research involving human pathogens, four biosafety levels (BSL-1 through BSL-4) are described in Section III of the CDC's *Biosafety in Microbiological and Biomedical Laboratories* (BMBL) and Appendix G, *Physical Containment* of the *NIH Guidelines for Research Involving Recombinant DNA Molecules*.

Each biosafety laboratory must, at a minimum, meet the requirements for laboratory facilities as stated in the BMBL: <http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm>. See Appendix 7-1 for a list of these design requirements.

1. Floors

- Floors must be durable and liquid tight.
Good Practice
- Floor materials must be nonabsorbent, skid-proof, resistant to wear, and resistant to the adverse effects of acids, solvents, and detergents.
NIH Design Guidelines
- For monolithic floors, either a 100-mm-high, readily cleanable, integrally coved sheet flooring base, or a readily cleanable, 100-mm-high, vinyl or rubber base must be used.
NIH Design Guidelines

2. Walls

- In BSL-3 laboratories, walls must be full height, extending to the structural deck above. For suites, suite walls must meet this requirement rather than individual

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laboratory rooms in the suite. The Fire Marshall may extend this requirement to include BSL-2 laboratories.

Crane and Riley, 1999 recommendation for BSL-3

3. Ceiling

- In BSL- 2 laboratories, drop ceilings must use smooth, cleanable tiles (Mylar face with a smooth surface, or the equivalent).

NIH Design Guidelines

- In BSL-3 laboratories, ceilings must be monolithic and easy to clean.

CDC-NIH BMBL

NIH Guidelines

USDA

NIH Design Guidelines

- In BSL-2 and BSL-3 laboratories, ceiling height must accommodate a 14-inch clearance for biological safety cabinet(s). The ceiling must be high enough to allow for canopy/thimble connection and the opening of thimble door(s), and so that the configuration of the ductwork will not interfere with airflow. A ceiling height of at least 10 feet is recommended. (Note: If the laboratory has a sprinkler system, local fire codes may require a clearance of 18 inches or more).

CDC-NIH Primary Containment for Biohazards

4. Offices and Eating Areas

- Formal offices should not be included in the laboratory. An area should be provided to allow researchers to record notes, possibly at a computer workstation with a laptop, or to fax materials.

USDA

- Eating and drinking is generally prohibited in BSL-2 and BSL-3 laboratories. An adjoining room must be provided for eating and drinking in each laboratory suite.

Good Practice

5. Windows

- Operable windows that open to the exterior, if present, must be fitted with fly screens. Note: USDA does not allow operable windows.

CDC-NIH BMBL; NIH Guidelines

- In BSL-3 laboratories, operable windows must not be allowed, in order to maintain air balance.

USDA; NIH Design Guidelines

6. Furniture and Casework

- Furniture and casework must be sturdy, capable of supporting anticipated loading and uses.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- Furniture and casework must be spaced so that areas around and under benches, cabinets, and equipment are accessible for cleaning.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

7. Biosafety Laboratories

- Benchtops must be impervious to water, and resistant to acids, alkalis, organic solvents, and moderate heat.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Benchtops should have marine/drip edging for spill control.
Health Canada, 2001
- Modular, mobile casework should be used for future flexibility.
Health Canada, 2001
- Furniture and casework should be designed with ergonomic considerations (e.g., adjustable work surface heights, selection of biological safety cabinets, adequate knee clearances for seated work, adequate toe clearances for standing work, wall cabinet heights, etc.).
Good Practice
- Fixed casework, if used, must be sealed or caulked to the walls on installation to facilitate cleaning and prevent harborage for vermin.
Good Practice; USDA
- Closed cabinets rather than open shelving must be used for storage.
USDA
- In BSL-2 and BSL-3 laboratories, chairs and other furniture used must be covered with a nonfabric material that can be easily decontaminated.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Tall or movable cabinets/shelves must be seismically anchored.
Good Practice
- Cabinets/shelves should have angled tops or be built up to the ceiling to facilitate cleaning.
Good Practice

7. Heating, Ventilation, and Air Conditioning (HVAC) Systems

- In BSL-2 and BSL-3 laboratories, HVAC systems must provide inward flow of air from rooms/areas of low hazard into rooms/areas of high hazard.
USDA; NIH Design Guidelines; ASHRAE, 2003
- In BSL-2 and BSL-3 laboratories, air must not recirculated to spaces outside of the laboratory or suite.
CDC-NIH BMBL; USDA; NIH Design Guidelines

8. Emergency Eyewash (Refer to Chapter 4, Emergency Eyewash and Safety Shower Equipment)

- Emergency eyewash specifications must meet the requirements in Chapter 4 of this design guide.
ANSI Z358.1, NIH Guidelines, 8 CCR, Section 5162
- An emergency eyewash must be available in BSL-2 and BSL-3 laboratories.
CDC-NIH BMBL
- Emergency eyewashes must be plumbed to drain or installed over a sink to facilitate monthly testing.
Good Practice

7. Biosafety Laboratories

- Eyewashes must be located in close proximity to splash hazards: less than 10 seconds' travel distance, and no more than 22 m from any point in the laboratory. Good practice requires that no more than one door must be opened in the line of travel.

NIH Design Guidelines, Good Practice

- Drench hoses must not be used in place of eyewashes.

ANSI Z358.1

9. Handwashing Sink

- Each laboratory must have a handwashing sink that is hands-free or automatically operated.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- The handwashing sink must be located near the exit, have chemical-resistant traps (for disinfectants), a coved backsplash, and a hot-cold water, pre-mixing faucet.

Good Practice

- The handwashing sink must be accompanied by a paper-towel dispenser and a hands-free soap dispenser mounted within easy reach.

Good Practice

10. Additional Design Considerations

- Provide provisions for locked storage in the building that meet the requirements of the California Medical Waste Management Act for medical waste interim storage, or have an autoclave in the building [see item 13, "Autoclave," in Section D (Basic Laboratory Design for Biosafety Level 3)].

California HSC, Section 118310; CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- Provide storage for halogen and/or flammable chemical disinfectants.

CFC

- For HIV, HBV, and HCV research laboratories and production facilities, follow Cal/OSHA's Bloodborne Pathogen Standard's additional design requirements.

8 CCR, Section 5193

D. Basic Laboratory Design for Biosafety Level 3 Laboratories

The Biosafety Officer (in collaboration with the Institutional Biosafety Committee) must approve the location and design of any BSL-3 facility, and has final authority to authorize the commencement of BSL-3 work.

The Biosafety Level-3 facility design and operational procedures must be documented. The facility must be tested for verification that the design and operational parameters have been met prior to operation. It is essential that the facility meets the required predetermined standards before putting the biocontainment facility into service.

CDC-NIH BMBL; USDA; Good Practice

1. General

- The laboratory must consist of an anteroom and laboratory rooms.

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CDC-NIH BMBL; NIH Guidelines; USDA

- The facility must have gas-impermeable walls, ceilings, and floors. Air gaps under doors are acceptable for directional airflow. If the door gaps are sealed, the laboratory suite must not leak gaseous decontamination materials.

CDC-NIH BMBL; NIH Guidelines; USDA

- Air balance must be set so air from low hazard rooms flows into rooms with higher hazards, and entry into the laboratory requires passage through two doors.

CDC-NIH BMBL; NIH Guidelines; USDA

- The laboratory must consist of high-quality room construction with special consideration given to joints, finishes, and penetrations.

Good Practice

- All shutoffs (steam, water, natural gas) must be external to containment.

Richmond, 2001

- All tall and/or heavy fixtures and equipment (e.g., biological safety cabinets, autoclaves, freezers, incubators, etc.) must be fitted with a seismic anchoring system/device engineered to withstand earthquake stresses equal to 7.0 on the Richter scale.

- The laboratory must be designed for ease of maintenance, so that access to critical mechanical equipment (ventilation ducts, fans, piping, etc.) is outside containment. Access panels are only allowed in some retrofits, and in those cases, the panels must be piano-type hinged and gasketed with gas-tight gaskets.

NIH Design Guidelines

- There should be a room for large equipment decontamination. The room should be capable of being sealed for decontamination with gaseous paraformaldehyde and must have a connection to the HVAC exhaust system.

Ellis and Kelley, 2001

- Consideration should be given to providing a separate equipment room (to isolate heat load and high hazard equipment like centrifuges) within the laboratory.

Crane and Riley, 1999

- Consideration should be given to providing a shared prep room within the laboratory.

Crane and Riley, 1999

- There should be provisions for a comfortable temperature compensating for the heat load from equipment and the gowning requirements for personnel in the laboratory. The temperature is lower for comfort, usually 68°F.

Lord, 2004

- CO₂ and other specialty gases must be plumbed from outside the laboratory into containment.

USDA recommendation

- Work surfaces, floors, walls, and ceilings must be designed, constructed, and finished to facilitate easy cleaning and decontamination.

7. Biosafety Laboratories

CDC-NIH BMBL; NIH Guidelines

- The facility must pass third-party inspection and tests to verify that design and operational parameters have been met. This should be done by a third party.

Good Practice

- The laboratory must be located away from public areas and corridors used by laboratory personnel who do not work in the BSL-3 laboratory.

USDA

- The laboratory must be separated from unrestricted traffic.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- The laboratory should be located away from regions that could impact directional airflow or differential pressure maintenance (elevators, exterior doors, laboratories with variable air volume systems or night set-backs, exterior walls with high wind or temperature fluctuations).

Crane and Riley, 1999

- An intercom or hands-free telephone must be located in each room and must be connected to a location that has personnel available for emergency response at all times work is being performed in a BSL-3 laboratory.

Lord, 2004

2. Anteroom

- The anteroom must consist of two doors for access to the laboratory.

CDC-NIH BMBL; NIH Guidelines;

- Anteroom doors should be interlocked or alarmed so only one door may be opened at a time, or placed sufficiently apart so that one person cannot open both doors at the same time. A manual override should be provided for emergency exit.

NIH Design Guidelines recommendation

- The anteroom, if functioning exclusively as a clean change room, must have ventilation separate from the laboratory's in order to maintain the containment envelope in the event of a ventilation failure.

Good Practice

- The anteroom must be large enough to provide for storage of clean gowns, laboratory coats, or uniforms that must be donned before entry and be removed before leaving the suite. The anteroom must also provide space for a log book, wall calendar, and a laundry hamper.

Good Practice

- The anteroom should be designed such that turbulent air currents formed when opening doors are minimized, i.e., doors are perpendicular to each other, anteroom is of sufficient size.

Jennette, 2000

- The anteroom must have communication capabilities installed.

Good Practice

- Space must be provided on or near the door for the conspicuous posting of the biohazard warning symbol, a list of personnel authorized to enter the area, and access rules.

CDC-NIH BMBL; NIH Guidelines

3. Floors

- Floors must be impermeable to liquids, monolithic/seamless, or have welded seams.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- Floors must be covered up the wall.

CDC-NIH BMBL; NIH Guidelines recommendation

- Floors must be easily cleaned, with chemical-resistant flooring (vinyl, or epoxy with fiberglass reinforcement) with a slip-resistant, smooth, hard finish.

CDC-NIH BMBL; NIH Guidelines; Eagleson Institute, 2004

- For monolithic floors, either a 100-mm-high, readily cleanable, integrally coved sheet flooring base, or a readily cleanable, 100-mm-high, vinyl or rubber base should be used.

NIH Design Guidelines

- For epoxy floors, if silicone sealants are used for penetrations, the silicone must be applied after the epoxy has been installed.

Ellis, 2004

4. Walls

- Suite walls should be full height extending to the structural deck above.

Crane and Riley, 1999 recommendation

- Walls must be durable, washable, and resistant to detergents/disinfectants (masonry, gypsum board, fiberglass-reinforced plastic, etc.).

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines; Ellis and Kelley, 2001

- Walls must be painted with durable glossy acrylic or epoxy paint.

Good Practice

- For epoxy paint, if silicone sealants are used for penetrations, the silicone must be applied after the epoxy has been installed.

Ellis, 2004

- Wall/ceiling penetrations should be kept to a minimum and sealed with nonrigid, nonshrinking, silicone or latex sealant; for fire rated walls, apply sealant before fire stopping.

CDC-ABSA, 1997 p. 90

- Corner guards and bumper rails must be provided to protect wall surfaces in high-traffic/impact areas.

NIH Design Guidelines

- A “pass-through” (for supplies, product, or equipment) requires approval of the Biosafety Officer.

Good Practice

5. Ceiling

- The ceiling must be washable and resistant to detergents/disinfectants.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- The ceiling must be painted with durable glossy acrylic or epoxy paint; for epoxy, if silicone sealants are used, the silicone must be applied after the epoxy.

7. Biosafety Laboratories

Ellis, 2004

- The ceiling must be of monolithic construction (i.e., gypsum board, not removable tiles).

Good Practice

- The ceiling must be high enough over Class II A2 biological safety cabinets (BSCs) to allow for a canopy/thimble connection or the opening of canopy/thimble door(s).

CDC-NIH Primary Containment for Biohazards

- Ceiling height should be at least 10 feet to allow for 14 inches of clearance above BSCs.

CDC-NIH Primary Containment for Biohazards, NSF-49

- Light fixtures must be surface or independently mounted.

NIH Design Guidelines

- If recessed lighting must be used because of ceiling height in a renovation, lighting penetrations are gasketed.

Good Practice

6. Offices and Eating Areas

- Eating and drinking is prohibited in BSL-3 laboratories. Formal offices should not be included in the laboratory suite.

7. Doors

- Doors must be self-closing and lockable.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- Doors should open inward (dependent on Fire Marshall requirements) or slide open. If sliders are used, they must be made of safety glass, and a trackless design should be considered. Note: Opening sliding doors causes less turbulence than standard doors. Pocket doors must not be used.

ABSA conference 2000

- Door between anteroom and corridor must have door sweep for pest control.

USDA

- Doors inside the suite should allow for an approximately 3/4-inch clearance underneath the door for directional airflow.

Ellis and Kelley, 2001

- Door openings should be sized to allow the passage of large equipment.

Good Practice

- Wall-door frame connection should be made airtight at time of frame installation.

Good Practice

- Doors and frames must be of solid finish construction, have required fire ratings, and include panic-hardware, hardware appropriate for high-use, and kick plates.

Good Practice; NIH Design Guidelines

8. Windows

- Windows (safety glass, permanently closed, sealed with silicone or latex sealant) should be installed so that the interior of the adjacent room, except change rooms and restrooms, is visible.

7. Biosafety Laboratories

Good Practice; CDC-NIH BMBL; NIH Guidelines; USDA

- Windows must not allow viewing from public areas.

Good Practice

- Interior sills must be sloped away from windows for ease of cleaning/minimize dust collection.

NIH Design Guidelines

9. Eyewash/Safety Shower

- An emergency eyewash must be located in each BSL-3 room.

CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- A combination emergency eyewash/safety shower unit must be located in near proximity to places if personnel are exposed to splash hazards (determined during programming).

8 CCR, Section 5162

- Emergency eyewash and emergency eyewash/safety shower units must be sited and installed in accordance with Section 5162 of 8 CCR.

8 CCR, Section 5162

10. Shower — Entry/Exit

- A shower may be required in ABSL-3 laboratories, insectaries, or with certain agents. The need for a shower will be determined during programming.

Good Practice

- When required, the entry/exit shower must be pass-through in design so that traffic flows in one direction, and dirty clothing/personal protective equipment (PPE) must not contaminate clean clothing, people, or equipment.

Good Practice

11. Plumbing

- All penetrations must be perpendicular to the surface and must be sealed to be gas-tight.

CDC-ABSA, 1997, p. 90

- Penetrations must be sealed with nonrigid, nonshrinking, silicone or latex sealant; for fire-rated walls, apply sealant before fire stopping.

CDC-ABSA, 1997, p. 90

- All pipes into the BSL-3 laboratories should be secured to prevent movement.

CDC-ABSA, 1997, p. 90

- Fixtures must be resistant to corrosion of bleach and other disinfectants.

Good Practice

- Back-flow prevention devices must be installed on all faucets (including industrial water).

CDC-ABSA, 1997, p. 90

- 6-inch P-traps should be installed if significant changes in pressure could occur.

CDC-ABSA, 1997, p. 90

- All pipes must be identified by use of labels and tags.

CDC-ABSA, 1997, p. 152

- Water supply control should be located outside the containment area.

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CDC-ABSA, 1997, p. 152

- Plumbing should discharge directly to a sanitary sewer.
CDC-ABSA, 1997, p. 152)

12. Sinks

- Handwashing sinks must be located in each room near the exit.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Sinks must be hands-free. Infrared sensors are preferable, but may not be suitable for all laboratories. In cases where infrared sensors cannot be used, knee-operated sinks are preferable to foot-operated.
CDC-NIH BMBL; NIH Guidelines
- Each sink must have chemical-resistant traps (for disinfectants), a coved backsplash, and a hot-cold water, pre-mixing faucet.
Good Practice
- Each handwashing sink must be accompanied by a paper-towel dispenser and a hands-free soap dispenser mounted within easy reach.
Good Practice

13. Autoclave

- Pass-through to the anteroom or support room; may be located outside the BSL-3 laboratory but within the building (only when no alternative is available).
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Autoclave must be equipped with interlocked doors.
USDA
- Decontamination cycles should be determined during programming; gravity and liquid cycles are typical.
Crane and Riley, 1999
- Appropriate autoclave size should be determined prior to purchase.
Crane and Riley, 1999
- The body of the autoclave must be located outside containment to provide easy access for maintenance.
Crane and Riley, 1999
- Sufficient space adjacent to the contaminated (input) door must be present for waste collection.
Good Practice
- Control panels should be located internal and external to containment.
Good Practice
- Bioseals or other equivalent means should be used to create a seal at the wall.
Lord, 2004
- The floor under the autoclave must be monolithic, seamless, or heat-sealed, coved, and water-tight.
NIH Design Guidelines
- Floor penetrations, if essential, must have a water and gas-tight seal at the monolithic floor.
NIH Design Guidelines

7. Biosafety Laboratories

- The walls and hard ceiling must have epoxy paint.
NIH Design Guidelines
- Exposed pipes should be insulated.
Crane and Riley, 1999; NIH Design Guidelines
- The autoclave should be seismically anchored.
Good Practice
- Fire sprinkler heads, if in the canopy, should be rated higher than the steam temperature.
Good Practice
- A curbed corrosion-resistant basin should be installed to prevent leakage.
Good Practice
- A canopy hood is provided over the exit door of the autoclave to contain heat and steam.
Crane and Riley, 1999; NIH Design Guidelines; ACGIH
- The installation must be signed off by a professional engineer.
Good Practice
- The autoclave room must have a minimum of 10 air changes per hour.
ACGIH

14. Life Safety

- Fire alarms must be clearly audible above ambient noise levels (low-frequency alarms for animal facilities).
Good Practice
- A wall-mounted ABC Dry Chemical fire extinguisher must be mounted near the exit door of the anteroom.
- Laboratory-safe refrigerators must be used to store flammable/combustible materials.

15. Alarms

- Alarms must be provided for:
 - Fire hazard
 - Ventilation failure
 - Differential pressures below 0.05" wg
 - –80°C freezers
 - Incubators (based on user programming)*NIH Design Guidelines; Good Practice*
- Alarms must be connected to the building control system.
NIH Design Guidelines
- Alarms must be audible and visible throughout the laboratory.
CDC-NIH BMBL (audible); NIH Design Guidelines
- Alarms should be differentiated from each other so that each can be easily identified.
Good Practice
- Alarms should be on UPS power.
Good Practice

16. Vacuum System/Pump

- Vacuum lines are protected with liquid disinfectant traps and HEPA filters, or their equivalent. Filters must be replaced as needed. An alternative is to use portable vacuum pumps (also properly protected with traps and HEPA filters).

CDC-NIH BMBL

- If an individual vacuum pump is used, it should be located in the laboratory. Noise and maintenance issues should be addressed.

USDA

17. Electrical

- Emergency power must be provided for:
 - HVAC (including controls)
 - Alarms
 - Emergency lighting
 - Biological safety cabinets
 - Storage freezers
 - Incubators

Ellis and Kelley, 2001; Lord, 2004; NIH Design Guidelines

- UPS power should be provided to alarms, and when possible, to biological safety cabinets.

Ellis and Kelley, 2001

- An independent circuit should be provided for each biological safety cabinet.

Ellis and Kelley, 2001

- Wall/ceiling penetrations should be kept to a minimum and must be sealed with nonrigid, nonshrinking, silicone or latex sealant; for fire-rated walls, apply sealant before fire stopping.

Ellis and Kelley, 2001

- Junction boxes should be cast and/or sealed airtight (e.g. closed cell foam compatible with gaseous paraformaldehyde).

Ellis and Kelley, 2001

- Light fixtures are surface- or pendent-mounted.

NIH Design Guidelines

- Circuit breakers are located outside containment and are labeled.

Good Practice

18. Heating, Ventilation, and Air Conditioning (HVAC) Systems

- In most cases, the HVAC system should be Constant Air Volume (CAV). Variable Air Volume (VAV) is not recommended.
Good Practice
- Electronic direct digital controls are used to manage the system.
USDA recommendation
- Recirculation of exhaust air must not be allowed.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- A dedicated exhaust system is required.
USDA
- The outside exhaust must be dispersed away from occupied areas and air intakes, or the exhaust must be HEPA-filtered.
CDC-NIH BMBL; NIH Guidelines; USDA (recommends locating the exhaust stacks on the roof and discharging upward at a velocity greater than 3,000 fpm); NIH Design Guidelines
- An exhaust HEPA may be required (see HEPA filter section).
- The need for a redundant exhaust fan should be determined by users, in order to allow continuing work.
Good Practice
- Air supply and exhaust system capacity must be $\geq 125\%$ of the laboratory's requirements to provide for future adaptability and flexibility.
ASHRAE, 2003
- The HVAC system must create directional airflow drawing air from rooms/areas of low hazard into rooms/areas of higher hazard.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Inward directional airflow must be maintained by providing 15% more flow of exhaust airflow than supply air (USDA) (minimum 200 cfm – Jennette, 2000), and sufficient to maintain the differential pressure between rooms in 0.05 – 0.20" Wg range.
USDA; Eagleson Institute; Jennette, 2000; CDC-ABSA, 1997 – p117
- The air balance must accommodate biological safety cabinet canopy/thimble connection or Class II type B2 cabinet exhaust requirements.
CDC-NIH Primary Containment for Biohazards; NIH Design Guidelines
- Inward directional airflow must be able to be verified before entry. Install a device(s) to indicate/confirm directional airflow into the laboratory (e.g., 0 – 0.20" Wg magnehelic gauges, digital differential pressure monitors, or both).
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- The BSL-3 lab must not become positively pressurized if the exhaust system fails. Whenever possible, electrically interlock the supply and exhaust fans.
CDC-NIH BMBL recommendation; USDA requirement; NIH Design Guidelines recommendation
- Exhaust ductwork must not be positively pressurized.
NIH Design Guidelines

7. Biosafety Laboratories

- Supply and exhaust dampers should be gas-tight and closable from outside the facility to facilitate decontamination with gaseous paraformaldehyde.
Ellis and Kelley, 2001; Lord, 2004
- Local visual and audible ventilation system failure alarms are required for laboratory personnel.
CDC-NIH BMBL; USDA; NIH Design Guidelines
- Air supply diffusers must be located so that airflow at the biological safety cabinet face is unaffected (laminar diffusers preferred).
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Ductwork should be located external to the laboratory; if exposed in the laboratory, ductwork is clear of walls to allow for cleaning, maintenance, and leak testing.
CDC-ABSA, 1997, p. 86.
- Ductwork should be gas-tight 316 stainless steel up to the HEPA filter (if present).
CDC-ABSA, 1997, p. 86
- All ducts must be constructed in a leak-tight manner with seams and joints usually welded airtight. The Biosafety Officer will determine if exhaust ductwork is to be welded.
USDA
- If the exhaust ductwork is welded, recommend welded joints for all connections except for the damper(s) (use flange and bolt connections for quick change-out in the future).
Ellis, 2004
- Coil units (for supplemental cooling) should not impact cleaning or provide a breach of containment.
USDA
- Limit elbows whenever possible to reduce the amount of background noise generated.
USDA recommendation

19. HEPA Filters

- The Biosafety Officer may determine that a HEPA-filtered exhaust system is not necessary after complete evaluation of the on-site conditions, including evaluations of:
 - Local code
 - Facility/building
 - Infectious agent
 - Conditions of the experiment or nature of animal used
 - An engineering study of the exhaust air plume that demonstrates that air must be directed away from occupied areas and air intakes
- HEPA filters, if provided on the exhaust system, must be "bag-in, bag-out," and the housing must accommodate gas decontamination and filter testing (gas-tight dampers and housing).
NIH Design Guidelines; ASHRAE, 2003

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- HEPA filter housings must be no more than five-feet high in order to facilitate filter change-out.
Good Practice
- When HEPA filters are installed, a magnehelic gauge or other pressure-monitoring device must be installed, with the display placed in the most accessible location that is practical, to measure pressure drop across the filters,
Good Practice
- A HEPA may be required on the autoclave exhaust, ultracentrifuge vent, and sewer vent.
Good Practice
- HEPA filters should comply with DOE-STD-3020-97 (or latest edition).
DOE-STD-3020-97
- Arrangements must be made to permit periodic leak testing of exhaust system HEPA filters. The system should comply with ASME AG-1.

20. Laboratory Furniture and Casework

- Laboratory furniture and casework must be sturdy, and capable of supporting anticipated loading and uses.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Laboratory furniture and casework must be spaced so that areas around and under benches, cabinets, and equipment must be accessible for cleaning.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Benchtops should be impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.
CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines
- Benchtops should have marine/drip edging for spill control.
Health Canada, 2001
- Modular, mobile casework should be used for future flexibility.
Health Canada, 2001
- Laboratory furniture and casework should be designed with ergonomic considerations (e.g., adjustable work-surface heights, selection of biological safety cabinets, adequate knee clearances for seated work, adequate toe clearances for standing work, wall cabinet heights, etc.).
Good Practice
- Fixed casework, if used, must be sealed/caulked to the walls on installation to facilitate cleaning and prevent harborage for vermin.
Good Practice; USDA; NIH Design Guidelines
- Fixed casework, if used, should be installed before the coved flooring so that the coving can extend up toe-kicks.
Ellis and Kelley, 2001
- Closed cabinets rather than open shelving should be used for storage.
USDA
- In BSL-2 and 3 laboratories, chairs and other furniture should be covered with a nonfabric material that can be easily decontaminated.

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CDC-NIH BMBL; NIH Guidelines; USDA; NIH Design Guidelines

- Tall or movable cabinets/shelves should be seismically anchored.

Good Practice

- Cabinets/shelves should have angled tops or be built up to the ceiling to facilitate cleaning.

Good Practice

21. Security

- Access controls should be provided to record entry and exit times and dates.

CDC-ABSA, 1997, p. 223

- Palm scan, proximity card, keypad entry with codes unique to each worker, cardkey, or equivalent, should be used.

CDC-ABSA, 1997, p. 223

- Access to mechanical and support areas must be limited.

CDC-ABSA, 1997, p. 223

- Security measures must equal or exceed the guidance set forth in Appendix F of the latest version of the CDC-NIH's *Biosafety in Microbiological and Biomedical Laboratories*. Note: USDA has specific security requirements; refer to *USDA Security Policies and Procedures for Biosafety Level-3 Facilities, DM 9610-001*.

CDC-NIH BMBL; USDA

22. Communications

- An intercom or hands-free telephone must be located in each room and must be connected to a location that has personnel available for emergency response at all times work is being performed in a BSL-3 laboratory.

Lord, 2004

- Wall/ceiling penetrations must be kept to a minimum and must be sealed with nonrigid, nonshrinking, silicone or latex sealant; for fire-rated walls, apply sealant before fire stopping.

23. Commissioning

- Commissioning should be performed by a third party in the presence of the Biosafety Officer.

Good Practice

- The Biosafety Officer will furnish checklists for the containment features to be evaluated, dependent on the facility design. Initially, the facility must pass a series of inspections and tests to meet standards that have been predeveloped, authorized, and specified in the design and construction documents before biohazardous agents are used in the facility. These are in addition to the desired outcomes by the commissioning team identified prior to initiation of construction activities.

CDC-NIH BMBL; USDA; Good Practice

- A properly designed and constructed biocontainment facility, including its structural and mechanical safety systems, must meet predetermined performance criteria and be operational upon completion of construction. The

7. Biosafety Laboratories

integrity of the critical components of the biological containment systems shall be verified by the testing and certification requirements listed below.

USDA; Good Practice

- Certification of the facility, including structural components and safety systems, must be included as part of the overall commissioning processes normally undertaken to verify that the design and construction meet applicable standards, and that the facility can operate in accordance with the design intent.

USDA; Good Practice

- Commissioning testing must also be performed without degradation to the facility or mechanical system that is being tested.

USDA; Good Practice

- All equipment and materials should be tested/evaluated prior to installation; duplicate testing is recommended.

Good Practice

- BSCs must be certified in accordance with NSF 49 after the BSC is anchored in its final location.

NSF/ANSI 49-04

- All HEPA filters must be tested to meet NSF 49 after installation.

NSF/ANSI 49-04

- Integrity of seals must be demonstrated by visual inspection.

Good Practice

- Integrity of epoxy coatings may be tested using ASTM D4541 Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers.

ASTM D4541

- The autoclave installation must be found to be proper as attested by the sign-off of a Professional Engineer.

- The autoclave must be tested to verify that it meets specified standards:

- Thermometers are calibrated
- Clocks and timers are calibrated
- Biological indicators are used to verify the autoclave's effectiveness

California HSC, Section 118215

- The operation of backflow preventers must be verified

- The ventilation system must be tested by:

- Ventilation ductwork and HEPA housings must pass pressure-decay testing under ASHRAE SMACNA Standard 126-2000 (Method of Testing HVAC Air Ducts)
- Measurements of airflow at each supply and exhaust diffuser
- Smoke testing to visually verify limited turbulence at face of BSC
- Smoke testing to visually verify airflow from areas of low hazard to areas of higher hazard
- Verification that air system failure alarms (exhaust, supply, room pressure) function and annunciate properly
- Air balance report must be provided to and verified by the Biosafety Officer

ASHRAE SMACNA 126-2000; Good Practice

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- Additional environmental protection (e.g., personnel showers, HEPA filtration of exhaust air, containment of other piped services, and the provision of effluent decontamination) should be considered if recommended by the agent summary statement, as determined by risk assessment, the site conditions, or other applicable federal, state, or local regulations.

Appendix 7-1. BMBL Requirements

1. Biosafety Level 1

- A door.
- A sink for hand washing.
- Designed for easy cleaning.
- Benchtops impervious to water and resistant to acids, alkalis, organic solvents, moderate heat, and chemicals used to decontaminate.
- Laboratory furniture capable of supporting anticipated loading and uses.
- Accessible spaces between and under benches, cabinets, and equipment.
- Windows fitted with fly screens (if they can be opened).

2. Biosafety Level 2

- BSL-1 requirements and good practices.
- Lockable, self-closing, fire-rated door that opens inward.
- Located away from public areas.
- Appropriately installed biological safety cabinets.
- Readily available eyewash station that complies with the requirements of Chapter 4 of this Guide.
- Adequate illumination for all activities.
- Consideration of inward flow of air without recirculation to spaces outside of the laboratory.
- Seismically anchored autoclaves.
- Good Practice for BSL-2 includes:
 - Floors with a slip-resistant, smooth, hard finish; are liquid-tight or monolithic/seamless or have welded seams; and that have a wall covered up 4-inches, or a cove-base installed to create a water-tight seal to the floor.
 - Walls that are durable, washable, and resistant to detergents/disinfectants (use durable glossy acrylic or epoxy paint or equivalent).
 - Protection of exposed corners and walls from damage by carts.
 - Wall/ceiling penetrations kept to a minimum and sealed with fire-retardant material.
 - Douse shower unit in near proximity. The safety shower/eyewash must comply with the requirements of Chapter 4 of this Guide.
 - Floor drain for autoclave.
 - A canopy hood located over each end of the autoclave.

3. Biosafety Level 3

- BLS-2 requirements and good practices.
- The laboratory is separated from areas that are open to unrestricted traffic flow within the building, and access to the laboratory is restricted. Passage through a series of two self-closing doors is the basic requirement for entry into the laboratory from access corridors. Doors must be lockable. A clothes-changing room may be included in the passage way.

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- Each laboratory room contains a sink for handwashing. The sink is hands-free or automatically operated, and is located near the room exit door.
- The interior surfaces of walls, floors, and ceilings of areas where BSL-3 agents are handled are constructed for easy cleaning and decontamination. Seams, if present, must be sealed. Walls, ceilings, and floors should be smooth, impermeable to liquids, and resistant to the chemicals and disinfectants normally used in the laboratory. Floors should be monolithic and slip-resistant. Consideration should be given to the use of coved floor coverings. Penetrations in floors, walls, and ceiling surfaces are sealed. Openings such as those around ducts and the spaces between doors and frames are capable of being sealed to facilitate decontamination.
- Benchtops are impervious to water and are resistant to moderate heat and the organic solvents, acids, alkalis, and those chemicals used to decontaminate the work surfaces and equipment.
- Laboratory furniture is capable of supporting anticipated loading and uses. Spaces between benches, cabinets, and equipment are accessible for cleaning. Chairs and other furniture used in laboratory work should be covered with a nonfabric material that can be easily decontaminated.
- All windows in the laboratory are closed and sealed.
- A method for decontaminating all laboratory wastes is available in the facility and utilized, preferably within the laboratory (i.e., autoclave, chemical disinfection, incineration, or other approved decontamination methods). Consideration should be given to means of decontaminating equipment. If waste is transported out of the laboratory, it should be properly sealed and not transported in public corridors.
- Biological safety cabinets are required and are located away from doors, from room supply louvers, and from heavily traveled laboratory areas.
- A ducted exhaust air ventilation system is provided. This system creates directional airflow, which draws air into the laboratory from "clean" areas and toward "contaminated" areas. The exhaust air is not recirculated to any other area of the building. Filtration and other treatments of the exhaust air are not required, but may be considered based on site requirements and specific agent manipulations and use conditions. The outside exhaust must be dispersed away from occupied areas and air intakes, or the exhaust must be HEPA-filtered. Laboratory personnel must verify that the direction of the airflow (into the laboratory) is proper. It is recommended that a visual monitoring device that indicates and confirms directional inward airflow be provided at the laboratory entry. Consideration should be given to installing an HVAC control system to prevent sustained positive pressurization of the laboratory. Audible alarms should be considered to notify personnel of HVAC system failures.
- HEPA-filtered exhaust air from a Class II biological safety cabinet (BSC) can be recirculated into the laboratory if the cabinet is tested and certified at least annually. When exhaust air from Class II BSCs is to be discharged to the outside through the building exhaust air system, the cabinets must be connected in a manner that avoids any interference with the air balance of the cabinets or

7. Biosafety Laboratories

the building exhaust system (e.g., an air gap between the cabinet exhaust and the exhaust duct). When Class III BSCs are used, they should be directly connected to the exhaust system. If Class III BSCs are connected to the supply system, it is done in a manner that prevents positive pressurization of the cabinets

- Continuous flow centrifuges or other equipment that may produce aerosols are contained in devices that exhaust air through HEPA filters before discharge into the laboratory. These HEPA systems are tested at least annually. Alternatively, the exhaust from such equipment may be vented to the outside if it is dispersed away from occupied areas and air intakes.
- Vacuum lines are protected with liquid disinfectant traps and HEPA filters, or their equivalent. Filters must be replaced as needed. An alternative is to use portable vacuum pumps (also properly protected with traps and filters).
- An eyewash station is readily available inside the laboratory.
- Illumination is adequate for all activities, avoiding reflections and glare that could impede vision.
- The Biosafety Level-3 facility design and operational procedures must be documented. The facility must be tested for verification that the design and operational parameters have been met prior to operation. Facilities should be re-verified, at least annually, against these procedures as modified by operational experience.
- Additional environmental protection (e.g., personnel showers, HEPA filtration of exhaust air, containment of other piped services, and the provision of effluent decontamination) should be considered if recommended by the agent summary statement, as determined by risk assessment, the site conditions, or other applicable federal, state, or local regulations.
- Laboratory separated from areas that are open to unrestricted traffic flow within the building, and access to the laboratory is restricted.

Appendix 7-2. Biological Safety Cabinets

1. Features

- All biological safety cabinets (BSCs) must meet the specifications within the most recent edition of the National Sanitation Standard 49 – Class II (Laminar Flow) Biohazard Cabinetry.
- CDC-NIH Primary Containment for Biohazards
- UV lights are not required nor recommended.
- All BSCs must be seismically anchored.

Good Practice

- All biological safety cabinets will be selected prior to HVAC design and be approved by the Biosafety Officer. Change orders will not be accepted afterwards.

Good Practice

- Class II A2 BSCs are recommended for most biohazard work, and are preferable to Class II A1 because of the negative plenum design of the A2. At a minimum, Class II A1 or Class II A2 BSCs must be used for biohazard work. Class I BSCs will not be approved.

Good Practice

- Class II A1 BSCs shall not be directly connected to the exhaust system.

CDC-NIH Primary Containment for Biohazards

- Class II A2 BSCs must connect to the exhaust system via an air gap (canopy or thimble), or exhaust directly into the laboratory. The canopy/thimble connection must provide access to the exhaust filter for testing of the HEPA filter. The canopy/thimble connection must have a ribbon streamer or like device attached to the edge to indicate the direction of flow.

CDC-NIH Primary Containment for Biohazards; 8 CCR, Section 5154.2

- Exhaust airflow in the canopy/thimble connection must be 120–125% of the BSC manufacturer's exhaust specifications. The canopy/thimble connection must be provided by the BSC manufacturer or as approved by the Biosafety Officer.

Good Practice

- Class II B2 BSCs must be used for biohazardous work involving greater-than trace amounts of flammable, volatile, or toxic chemicals. Class II B2 BSCs must be directly (hard) connected to the exhaust system. Class II B2 BSCs must have fan interlocks, so that when the exhaust fan is manually shut off, the internal blower of B2 BSCs shuts off.

CDC-NIH Primary Containment for Biohazards; 8 CCR, Section 5154.2

- Class III BSCs must be directly (hard) connected to an exhaust system dedicated to that Class III BSC. If they are connected to the supply system, it is done in a manner that prevents positive pressurization of the BSC. By definition, Class III BSCs have two HEPA filters in the exhaust system.

CDC-NIH Primary Containment for Biohazards; 8 CCR, Section 5154.2

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- Class II B2 and Class III BSCs must not be manifolded with other types of BSCs or fume hoods. Class II B2 BSCs can be manifolded with other Class II B2 BSCs.

Good Practice

- Redundant exhaust fans should be supplied for Class II B2 BSC exhausts, since the BSC's containment depends on the building's exhaust system.

ASHRAE, 2003

- 14-inch clearance above the cabinet must be provided for accurate air velocity measurement across the exhaust filter surface and for exhaust filter changes. When the BSC is hard-ducted or connected by a canopy connection to the ventilation system, adequate space must be provided so that the configuration of the ductwork will not interfere with airflow.

CDC-NIH Primary Containment for Biohazards

- Ergonomic considerations shall be included. The BSC shall have adjustable height at a minimum. Additional considerations include a short front grille to minimize reach distance, an angled front sash, and elbow rests.

Good Practice

- Natural gas is not recommended. If provided, the gas line shutoff valve must be easily accessible. The gas supply line must have flex gas lines and a pipe union between the shutoff valve and the wall.

NIH Design Guidelines

- Where BSCs are directly (hard) connected to the exhaust system, an audible and visual alarm system to alert the user indicating the loss of exhaust flow in the external duct shall be used.

8 CCR 5142.2

2. Location

- The BSC must be located at least six feet from doors and high-traffic areas, and such that air supply diffusers do not affect airflow at the BSC face.

CDC-NIH BMBL; USDA

- BSCs must be placed out of the direct traffic pattern of the laboratory. Air supply diffusers or exhaust vents shall not be placed directly over or in front of BSCs where the movement of air can affect the airflow of the cabinet.

NIH Design Guidelines

- The BSC must be located away from the entry to the laboratory (i.e., the rear of the laboratory away from traffic), since people walking parallel to the face of a BSC can disrupt the air curtain. The air curtain created at the front of the cabinet is quite fragile, amounting to a nominal inward and downward velocity of 1 mph. Open windows, air supply registers, or laboratory equipment that create air movement (e.g., centrifuges, vacuum pumps) must not be located near the BSC. Similarly, chemical fume hoods must not be located close to BSCs.

CDC-NIH Primary Containment for Biohazards

- If multiple BSCs are located across from each other, they must be offset for personnel clearance if placed in close proximity to another BSC, and away from windows where convection may affect airflow at the BSC face.

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Crane and Riley, 1999

- BSCs must have clearance of at least six inches from rear and side walls for cleaning and maintenance, and to ensure that the air return to the laboratory is not hindered.

CDC-NIH Primary Containment for Biohazards

- If Class II A2 BSCs with a canopy/thimble connection or Class II B2 BSCs are used, the model must be selected before the HVAC is designed for proper duct penetration placement.

Ellis and Kelley, 2001

3. Certification

- Biosafety cabinets must be certified by a qualified independent testing organization prior to building acceptance or for installations not involving significant building modifications, and before use with biohazards.

CDC-NIH BMBL; 8 CCR 5142.2D

8. ADDITIONAL REQUIREMENTS FOR RADIOACTIVE MATERIAL LABORATORIES

A. Scope.....	8-1
B. Basic Laboratory Design.....	8-1
C. Ventilation Considerations	8-2
D. Radioactive Material Waste Management	8-2

A. Scope

All radioactive materials are governed by the terms and conditions of the Radioactive Materials License, issued by the Nuclear Regulatory Commission or the Department of Health Services, Radiologic Health Branch.

B. Basic Laboratory Design

1. A facility for handling radioactive material shall be located and designed so that the radiation doses to persons outside the facility can be maintained below applicable limits and are As Low As Reasonably Achievable (ALARA).

NCRP Report, No. 127, Section 4.1

10CFR 20

40 CFR 191

2. Sinks shall be constructed of impervious material such as stainless steel. Faucets should be foot-, elbow-, or knee-operated. Plumbing should be smooth and easily cleaned.

State of California, Department of Health Services, Radiologic Health Branch, Guide for the Preparation of Applications for Medical Programs (RH 2010 4/90)

NUREG 1556, Vol. 7, Appendix K

Safe Handling of Radionuclides, 1973 Edition, Section 3.3.3

Safe Handling of Radioactive Materials Handbook 92

3. When required, radiation shielding shall be approved by the Radiation Safety Officer (RSO).

17 CCR

8 CCR

State of California, Department of Health Services, RH 2010 4/90

This applies to high-energy gamma and x-ray emitters. Facility designed shielding is not usually needed for alpha or beta emitters.

4. The RSO will determine whether "High, Very High, or Airborne" radiation areas exist, and will specify requirements.

17 CCR

10CFR 20

10 CFR 20.1601-2

NCRP, No. 127, Section 4

8. Additional Requirements for Radioactive Material Laboratories

5. Floors shall be constructed of a seamless material, preferably made of a single piece without grouting. The surface should be sealed and uncarpeted to allow easy cleaning.

NCRP Report, No. 127, Section 4.6

C. Ventilation Considerations

1. Facilities performing procedures that involve airborne radionuclides shall be equipped with ventilation that will limit air concentrations to levels that are ALARA and are less than occupational exposure limits. Ventilation systems shall prevent the escape of the airborne contaminants to adjacent non-use areas such that air concentrations in those areas do not exceed those allowed for unrestricted areas.

*State of California, Department of Health Services, RH 2010 4/90
10 CFR 20, Appendix B*

2. Hood inserts are only permitted for iodination procedures specifically approved by the Radiation Safety Officer.

NCRP Report, No. 127, Section 4.5

3. Nuclear air cleaning (filtration) systems on major installations shall be designed in accordance with ASME N509 or AG-1, and should be designed in accordance with N509 and AG-1 whenever possible for all installations. The radiation exposure of individuals from the radioactive materials retained on the filter(s) shall be evaluated. Each filter stage shall be designed and located to facilitate independent testing in accordance with ASME N510 or AG-1. HEPA filters used in the last stage of a system just prior to discharge into occupied locations or the environment shall comply with DOE-STD-3020-97 (i.e., will be "nuclear grade").

NCRP Report, No. 127, Section 4.5

DOE-STD-3020-97

ASME AG-1

ASME N509

ASME N510

Each filter stage should be designed and located to facilitate independent testing according to applicable standards. Proper design will allow the filters to be changed easily while minimizing the potential for release of radioactivity and worker exposure. Push-through, bag-in/bag-out systems are preferable. While closed-face filters appear to be convenient to use, proper in-place testing is virtually impossible, so they should not be used whenever the filter will be subjected to in-place testing. Higher-efficiency filters, such as ULPA filters, are available, but they are not as rugged as a nuclear-grade HEPA filter, and they should not be used for nuclear air cleaning. It is noted that AG-1 is supplanting N509 and N510.

D. Radioactive Material Waste Management

1. Piping systems should be designed to minimize connections between sanitary and laboratory drains.

8. Additional Requirements for Radioactive Material Laboratories

NCRP Report, No. 127, Section 4.6
NUREG 1556, Vol. 7, Appendix K

2. To reduce unnecessary exposure, radioactive waste should be stored in areas separate from work places.

NCRP Report, No. 127, Section 4.6

9. ADDITIONAL REQUIREMENTS FOR LABORATORIES WITH IRRADIATORS AND/OR RADIATION-PRODUCING MACHINES

A. Introduction:	9-1
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C. Basis For Shielding Specifications:	9-2
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A. Introduction

Machines and sealed/contained sources that produce ionizing radiation are common in research labs. Radiation sources can take many forms, from high-energy accelerators that require special shielding as well as extensive engineering and administrative controls, to sedimeters that produce x-rays of such low energy and intensity that minimal controls are required. This wide variation in sources makes it difficult to write detailed guidelines for all radiation sources and emphasizes the importance of involving the facility Radiation Safety Officer (RSO) or designee in the processes related to design, installation, acceptance testing, and operation of all such sources.

The purpose of this chapter is to identify common radiation sources that produce ionizing radiation (machines or sealed/contained radioactive sources) at research facilities and to give general guidelines regarding the planning, installation, storage, and use of these sources. For details, always refer to the facility RSO or designee.

Though these recommendations deal mostly with radiation sources found in research facilities, most campuses have medical x-ray facilities as well (e.g., hospitals, medical and dental clinics); therefore, limited comments regarding these facilities have been included. Typical sources include:

- Machines:
 - X-ray radiographic and/or irradiation facilities
 - Accelerator facilities
 - Analytical x-ray machines (e.g., x-ray diffraction, electron microscopes)
 - Cabinet radiography units
 - Accelerators used for radioisotope production
- Radioactive Materials Sources:
 - Sealed sources
 - Irradiators
 - Moisture/density gauges
 - Contained sources (sources used to irradiate, but do not satisfy the requirements of a sealed source)

B. General Requirements/Considerations

Early in the planning stages when an irradiator or x-ray producing device is planned for installation in a building, the RSO shall be consulted. There are numerous regulatory and design requirements that shall be addressed (e.g., registration, licensing, and shielding).

1. Registration of machines: Many states require that machines be registered within thirty days after installation. In California, machines shall be registered within 30 days of acquisition. Machines are typically registered by the facility RSO or designee.
17 CCR 30108 - 30146
2. Licensing of radioactive materials: Most sealed and unsealed sources that contain radioactive materials shall be licensed by the appropriate regulatory agency. Licensing is by the respective State or the Nuclear Regulatory Commission. All uses of radioactive materials are approved by the facility RSO and/or Radiation Safety Committee (RSC).
17 CCR 30170-30237
3. When constructing or reconstructing a room that will house a radiation machine capable of operating at a potential in excess of 500 kVp, the registrant shall notify the Department of Health Services at least 60 days prior to the possession of the machine, or 60 days prior to the commencement of the construction or reconstruction.
17 CCR 30108 – 30110
4. The shielding design shall be prepared by a “qualified expert” as defined in NCRP 49. (NCRP 147 is now available, but has not yet been adopted by the State of California). Shielding designs for radiation therapy facilities in California shall be prepared by an individual who is on the list of physicists approved by the State of California to perform shielding designs and evaluations for radiation therapy facilities.
17 CCR 30312(b)(5)
5. All shielding designs, including final construction drawings, shall be approved by the facility RSO and/or RSC.
Facility radioactive material license

C. Basis for Shielding Specifications

1. Exposure/dose limits: Facilities shall be designed such that the exposure limits specified in 17 CCR and 10 CFR for controlled and uncontrolled areas are not exceeded when use and occupancy factors are taken into account.
 - In accordance with the intent of ALARA (As Low As Reasonably Achievable), shielding should be designed with the goal of not exceeding 10 mrem/week in controlled areas.

9. Additional Requirements for Laboratories with Irradiators and/or Radiation-Producing Machines

- In accordance with 10 CFR 20.1301, shielding should be designed so that the dose in uncontrolled areas does not exceed 2 mrem in any one hour.

10 CFR 20 and 35

10 CFR 20.1201, 1301 and 1302

17 CFR 30305(a) (5)

24 CCR 2 3101C–3104C

24 CCR 12-31C-101

2. References Related to the Specification of Shielding

NCRP 35, 39, 49, and 51: In these references, the shielding specified for uncontrolled areas is based upon an exposure limit of 500 mrem/yr rather than the current 100 mrem/year. In addition, some of the methodologies and assumptions (e.g., radiation attenuation data) have been updated since they were originally published. Even though there have been changes in some regulations, methodologies and assumptions, the basic information contained in these publications is sound and can serve as a basis for conservative shielding specifications if they are corrected for the current exposure limits. The California Building Code requires the use of NCRP 49 even though the NCRP has recently issued an update to that report (NCRP 147).

3. Recommendations in Selected *Health Physics* and *Medical Physics* Journal Article

In the following journal articles, new methodologies, assumptions and attenuation data are described for specifying shielding. The concepts and practices proposed in these publications have been incorporated into NCRP 147. Full citations are contained in Appendix B of this Laboratory Safety Design Guide.

Dixon, R.L., On the Primary Barrier in Diagnostic X-Ray Shielding, Med. Phys. 21, 1785-1794 (1994)

Dixon, R.L., and Simpkin, D.J., Primary Barriers for Diagnostic X-Ray Facilities: a New Model, H. Phys. 74, 181-189 (1998)

Simpkin, D.J., PIN A General Solution to the Shielding of Medical X and Gamma Rays by the NCRP Report 19 Methods, H. Phys. 52, 431-436 (1987)

Simpkin, D.J., Shielding Requirements for Mammography, H. Phys. 53, 267-269 (1987)

Simpkin, D.J., Shielding a Spectrum of Workloads in Diagnostic Radiology, H. Phys. 61, 259-261 (1991)

Simpkin, D.J., Diagnostic X-Ray Shielding Calculations for Effective Dose Equivalent, H. Phys. 21, 893 (1994)

Simpkin, D.J., Transmission Data for Shielding Diagnostic X-Ray Facilities, H. Phys. (1995)

Simpkin, D.J., Evaluation of NCRP Report 49 Assumptions on Workloads and Use Factors in Diagnostic Radiology Facilities, Med. Phys. 23(4) (1996)

Simpkin, D.J., Scatter Radiation Intensities About Mammography Units, H. Phys. (1996)

Simpkin, D.J., and Dixon, R.L. Secondary Shielding Barriers for Diagnostic X-Ray Facilities; Scatter and Leakage Revisited, H. Phys. 74, 350-365 (1998)

D. Special Considerations

1. Activated shielding and source components: Walls, shielding, and source components may become radioactive by the process of activation in facilities with high-energy radiation sources. The extent and magnitude of the activation is

9. Additional Requirements for Laboratories with Irradiators and/or Radiation-Producing Machines

dependent on many factors including source “energy” and “on time.” In many cases activation occurs but is not a significant concern, since the radioactive materials produced have very short half-lives. The extent and magnitude of activation should be evaluated for sources with energies greater than 10 MeV. When appropriate, such facilities should be designed such that activated materials may be removed easily.

Good Practice

2. Exhaust ducts and collectors shall be located and/or shielded such that personnel exposures, along their route of travel and at the collector, are ALARA and do not exceed regulatory limits. Collectors shall be equipped with bag-in/out capability and located such that there is adequate space to change out collectors without contaminating uncontrolled areas and with minimum disruption of uncontrolled operations. Since such ducting and associated collectors are often located in uncontrolled areas occupied by individuals who are unfamiliar with radiation, even small exposures may be alarming to the occupants; therefore, it may be advisable to design shielding to reduce exposures far below regulatory limits or to provide additional training to the occupants regarding the effects of radiation.

Good Practice

3. Radiation source transport systems (“rabbits”) shall be routed and/or shielded such that exposure limits are not exceeded in controlled or uncontrolled areas during routine operations or emergency situations (e.g., stuck source). To plan for emergency situations, an accident analysis shall be conducted and an emergency response plan prepared that will deal with any hazardous conditions that were identified.
4. Height and extent of shielding: For most single-floor facilities with machines with energies less than 150 kVp, shielding shall be 7-feet high. In multi-floor/level facilities, shielding in walls may need to be higher than 7 feet. For single-floor facilities with high-energy sources that can produce “skyshine,” shielding should extend to the ceiling, and the ceilings themselves may require shielding.

NCRP 49

5. Nails/screws penetrating shielding material do not need to be capped with lead in walls that require less than 4 lbs/ft² of lead.

Acceptable practice in CA

6. Operator protection: Source controls shall be located such that no first scattered radiation reaches the control area (an exception to this general rule applies to DEXA bone density, and veterinary and dental units) and that exposures from primary and secondary radiation will not exceed regulatory limits when use and occupancy factors are taken into account.

17 CCR 30311(b)(2) and 30314(b)(2)

Good Practice

7. Shielding required to protect unexposed film or emulsions stored in areas near radiation sources shall be evaluated on an individual basis. The shielding required to protect personnel from radiation is often inadequate to protect unexposed film or

9. Additional Requirements for Laboratories with Irradiators and/or Radiation-Producing Machines

emulsions stored near radiation sources.

Good Practice

8. Design to physically support shielding (e.g., weight, “cold flow”): The structure of the facility shall be designed (evaluated and updated for renovated facilities) to support required shielding. It is important to recognize that some shielding materials (e.g., lead) can “cold flow” with time (particularly for tall and thick sections). It is necessary to support shielding in a way that will address this problem or to use an alternative shielding material (e.g., iron, concrete).
9. Design to physically support the equipment: Some radiation sources and associated shielding are extremely heavy, so the structure of the facility may need to be specially designed (evaluated and updated for renovated facilities) to support it.
10. Seismic considerations: In California, shielding and equipment shall be designed and installed to meet seismic-restraint requirements.

State and local building requirements

11. Hazards associated with moving: Heavy shields, and high-voltage and high-magnetic fields are often present around radiation sources. Often, special administrative and engineering controls are required to deal with these hazards safely.

29 CFR 1910

8 CCR

12. Exhaust systems for hazardous materials (e.g., ozone, cryogenics, gaseous activation products) produced or present around radiation sources: Exhaust systems need to be designed to maintain exposure levels for hazardous materials below the respective occupational exposure limits. Care shall be exercised in selecting the discharge points for these exhaust systems.

29 CFR 1910

8 CCR

ACGIH Industrial Ventilation, a Manual of Recommended Practice, latest edition

13. Interlocks: Often required on access doors to radiation sources or on required shielding components that are movable. The interlocks are required to disable the production of radiation if doors are not closed or if shielding is not positioned as required to provide adequate protection to controlled or uncontrolled areas. Such interlocks shall be fail-safe and tamper-resistant.
14. Emergency “Off” (mushroom) switches: Typically required in areas where exposures to individuals could exceed the limits established by the RSO and/or RSC if administrative or engineering controls should fail. Such switches shall be centrally located and in sufficient number so each potential user has convenient access.
15. Warning lights, audible signals, and signs: Warning lights and audible signals shall be in compliance with the requirements in 10 CFR 20.1601. Signage shall be in compliance with the requirements in 10 CFR 20.1902. Exceptions for the “High Radiation Areas” caused by radiographic and fluoroscopic machines used solely in the healing arts are specified in 17 CCR 30305 (c) (which requires a “Caution X-

9. Additional Requirements for Laboratories with Irradiators and/or Radiation-Producing Machines

Ray” sign in the areas or rooms that contain permanently installed x-ray machines as the only source of radiation). These sources used exclusively in the healing arts are exempt from the controls of 10 CFR 20.1601 if they are in compliance with 24 CCR, Chapter 31C, Sections 3101C–3104C.

10 CFR 20.1601

10 CFR 20.1902

17 CCR 30305 (c)

17 CCR 30305 (d)

24 CCR 3101C- 3104C

16. Radiation area monitors: Typically required when exposure rates are such that the exposure of an individual in the area could exceed institutional administrative controls specified by the facility RSO and/or the RSC.

E. Pre-Use Considerations

1. Inspection during construction: Shielding should be inspected by the facility RSO or designee during installation to assure that it is installed according to specifications. Deficiencies shall be corrected prior to operation of the facility. After construction, the attenuation of shielding can be verified using a radiation source. Attenuation measurements can be used to determine the overall effectiveness of shielding, but cannot easily find small voids in the shielding.
2. Radiation survey before use of a radiation source: A radiation survey of adjacent controlled and uncontrolled areas shall be conducted by the facility RSO or designee to assure that shielding is adequate to meet regulatory exposure limits and/or limits specified in the shielding design. The radiation survey shall be conducted under conditions that are representative of actual operating conditions at the facility. Deficiencies shall be corrected prior to operation of the facility.

17 CCR 30312 (b) (5) for therapy facilities

Good Practice for non-therapy facilities

F. Facilities/Sources With Special Considerations

1. X-ray diffraction: If the radiation source is totally surrounded by a shielded enclosure with “fail-safe” interlocks on all access doors, no additional shielding is usually required. Contact the RSO for details.
2. Moisture/density gauges: Special consideration should be given to the storage location for such sources. Storage locations may need to be shielded or in remote locations where the exposure limits for controlled and uncontrolled areas are not exceeded. Contact the RSO for details. Adequate security measures for the storage area and transportation need to be provided to prevent unauthorized removal. A minimum of two locks should be placed between the radioactive source, and the public and transport vehicles should possess a security device (such as an alarm) to deter unauthorized use or theft of the vehicle.
CA DHS Radiation Safety Advisory of 3/6/03 – Security of Licensed Materials
3. Electrical equipment that produces radiation incidental to its operation for other

purposes but does not produce radiation in an area likely to cause any individual to receive in excess of 500 mrem in a year does not need to be registered with the State.

17 CCR 30125 (b)

G. Considerations for Facilities/Sources Not Covered in Detail by These Recommendations

Though the following facilities/sources are not covered specifically by these recommendations, most of the “General Requirements/Considerations” apply, although additional requirements may also apply. It is important to remember that all facilities with radioactive materials and/or radiation producing machines shall be reviewed and approved by the facility RSO and/or the RSC prior to installation/operation. Due to the many safety and regulatory aspects related to the design, installation, commissioning, and operation of such facilities, early involvement of the facility RSO is advisable. Unanticipated corrective actions can result in unpleasant, unnecessary, and costly delays.

Clinical and Veterinary Facilities:

- Diagnostic Medical:
 - Radiographic (e.g., fixed, portable, mammography)
 - Fluoroscopic (e.g., fixed, portable)
 - Cine
 - Computed Tomography (CT)
 - Bone density
 - Nuclear medicine imaging
 - Positron Emission Tomography (PET)/CT imaging
- Diagnostic Dental:
 - Radiographic
 - Cephalometric
 - Panoramic
- Therapy:
 - Accelerators
 - Brachytherapy sources
 - High Dose Rate (HDR) Afterloaders
 - Gamma Knife
 - Ortho-voltage units
 - Grenz rays
 - Intravascular brachytherapy devices

Some Important Considerations For Facilities/Sources Not Covered In Detail By These Recommendations:

1. Clinical Facilities shall include these features:
 - Equipment for human use shall meet FDA requirements.

9. Additional Requirements for Laboratories with Irradiators and/or Radiation-Producing Machines

- Equipment Commissioning: All equipment shall be checked for compliance with regulatory requirements prior to use on patients. Equipment at JCAHO-accredited facilities shall be commissioned by a “Qualified Expert” prior to use.
- Patient viewing and communication: When patients are being exposed/irradiated, the operator shall have the ability to communicate with and view the patient continuously from an area protected from primary, secondary, and first-scatter radiation (i.e., a controlled area). Exceptions to this general rule are operators of portable diagnostic x-ray equipment used at nonfixed locations, dental x-ray equipment, and most nuclear medicine imaging equipment. For most of these exceptions, the operator shall be at least 6 feet from the source of radiation and out of the primary beam.
- Warning lights, audible signals, and signs:
 - Areas or rooms that contain permanently installed x-ray machines as the only source of radiation shall be posted with a “CAUTION X-RAY” sign or signs in lieu of other signs required by the 10 CFR, Part 20, Section 20.1902, as incorporated by reference in Section 30253.
 - High-radiation areas caused by radiographic and fluoroscopic machines used solely for the healing arts are exempt from the controls in 10 CFR 20.1601 if they are in compliance with 24 CCR, Chapter 31C, Sections 3101C–3104C.

17 CCR 30305 (c)

17 CCR 30305 (d)

2. For dental radiographic facilities, the ordinary walls in a building (two layers of 5/8-inch drywall) often provide adequate shielding to protect surrounding areas. It should be noted that one of the common layouts for dental equipment puts the head of the dental chair adjacent to central work or patient areas. Unless modified, this common layout can result in the unacceptable practice of exposing the central work or patient areas to unshielded primary radiation. Because of the many variables, the shielding in each dental x-ray room shall be evaluated by the facility RSO or designee.

17 CCR 30311

JCAHO recommendations

3. Shielding for each veterinary radiographic facility or room shall be evaluated (designed and tested) by the facility RSO or designee. It should be noted that operator control booths are not always required for these facilities.

17 CCR 30314

4. Provision should be made for storage and inspection of leaded aprons in medical fluoroscopic and cine facilities.

Good Practice

5. Medical bone density units seldom require operator control booths or additional shielding; however, each unit should be evaluated by the facility RSO or designee.

Good Practice

6. Filters are required on hospital fume hood exhaust systems for OSHPD 1, 2, 3,

9. Additional Requirements for Laboratories with Irradiators and/or Radiation-Producing Machines

and 4 facilities that may release radioactive materials. The filters will have a 99% efficiency based on the DOP test method. Fume hood exhaust ducts will be constructed of stainless steel.

24 CCR 409.4

24 CCR 409.3

10. ADDITIONAL REQUIREMENTS FOR LABORATORIES USING NON-IONIZING RADIATION (NIR) SOURCES, INCLUDING LASERS

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A. NIR Safety Basic Requirements

1. Laboratories using non-ionizing radiation sources shall be designed to minimize radiation exposure to personnel and the environment.
Good Practice
ANSI Z136.1 4.1
ANSI C95.1 4.1
2. Laboratory designs shall utilize appropriate engineering and administrative controls to prevent radiation exposure in excess of the applicable regulations, standards, and guidelines.
Good Practice
ANSI Z136.1 4.1
ANSI C95.1 4.1
3. Laboratory designs should be forwarded to the campus Radiation Safety Officer (RSO) or Laser Safety Officer (LSO), as appropriate, for NIR safety review and approval prior to being released for bid or beginning construction (for internal projects that are not put up for bid).
Good Practice
ANSI Z136.1 4.1
ANSI C95.1 4.1

B. Controlling Access to Laser Areas

1. Doors providing access to spaces containing open-beam Class-4 lasers shall be fitted with interlocks to prevent emission from the lasers if the doors are opened, and to deny outside-to-inside entry during laser emission. Design of interlocks should favor the use of shutters or laser beam dumps to limit emission. Laser power supply shutoffs should not be used except where no other alternative exists.

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Laser operations in which personnel entering rooms can immediately encounter a potentially harmful level of laser radiation are not permitted.

ANSI Z136.1 4.3.10.2.2

A lab containing a number of lasers and/or interlocked optical benches or beam paths may require a programmable logic controller to coordinate interlock functions and warning annunciations at the entrances.

2. All doors to Class-3b and Class-4 laser areas shall have ANSI Z136.1 (2000) specification laser warning signs. Signs should be mounted such that they are visible near the doorway and at some distance from it. Signs should not be mounted above doorways, as these can be overlooked. Lighted laser warning signs (or status panels that indicate the room access status) shall be used for Class-3b and Class-4 lasers.

Good Practice

ANSI Z136.1 4.3.9.4.2

Electronic displays may be preferable for conspicuousness and/or to relate instructions for labs with complex laser setups. Electronic displays may be simple, with features ranging from on-off switch controls, to enunciators for systems interfacing laser, room access, and beam enclosure interlocks. Modern light-emitting diode (LED) displays and programmable logic controllers (PLCs) can display access status and specify laser eyewear or personal protective equipment (PPE) requirements. Electronic displays may also be used in addition to conventional warning signs.

3. Partitions, dogleg entrances, or other provisions shall be made to allow persons to don laser protective eyewear and other required PPE before entering spaces where beam hazards exist or could exist. Preferably, this provision should be made before they enter the lab.

Good Practice

Laser eyewear is vulnerable to physical damage and is expensive, so provisions need to be made for proper storage to prevent scratching or other damage.

4. Appropriate barriers shall be provided to prevent Class-3b or Class-4 laser beams from leaving the confines of a laser lab through doorways, windows, etc.

ANSI Z136.1 4.3.9.4.2

NOTE: ANSI Z136.1 recommends barriers for Class-3b lasers and mandates barriers for Class-4 lasers. Laser labs could be set up in rooms with windows, but should not be set up in a space with operable windows. Windows need to be covered with appropriate materials (opaque at the laser wavelength and compatible with the beam energy) to prevent beams from escaping. A simple metal plate with a diffusely reflective finish at the laser wavelength is adequate.

C. Beam Path Management

1. Provisions shall be made to enclose Class-3b or Class-4 laser beams whenever possible. Class-3b or Class-4 laser beam paths that cross between optical

10. Additional Requirements for Laboratories Using Non-Ionizing Radiation (NIR) Sources, Including Lasers

tables/equipment benches or pass through barriers shall be properly enclosed and prominently marked identifying the hazard. All enclosures shall be compatible with the laser wavelength and beam power. All laser-beam paths shall be maintained at a height either above or below the eye level of standing/sitting persons who may be exposed.

Good Practice

ANSI Z136.1 4.3.6.1 and 4.3.6.3

2. Laser enclosures, beam stops, beam barriers, and other exposed surfaces shall be diffusely reflective at the laser wavelength used. Surfaces that may create a specular reflection at the laser wavelength shall not be used. Optimally, potentially exposed surfaces should be painted jet black.

Good Practice

D. Fire Safety for Lasers

1. Flammable/combustible construction materials shall be avoided in spaces housing Class-4 lasers. Materials used for beam stops or beam barriers shall not off-gas, nor be combustible at the beam power used. Curtains used as laser barriers shall not off-gas, and shall be flame-retardant or, preferably, flame-proof or laser-rated.

ANSI Z136.1 4.3.8

NFPA 115 4, 6

NFPA 115 advises that laser beams with irradiances above 2 W/cm^2 should be regarded as a fire hazard

2. Provisions shall be made for the safe storage of laser dye solutions, solvents, and other flammable materials well away from the laser use area.

8 CCR 5191

NFPA 115 9

E. Electrical Safety for Lasers

1. Appropriate grounding connections shall be provided for laser power supplies and other electrical components. All optical tables shall be properly grounded. To facilitate use, all grounding connections should be properly marked.

Good Practice

8 CCR 2395, 2889

2. Electrical systems shall be marked to show voltage, frequency, and power output. All high-voltage sources shall be properly marked and secured to prevent accidental access.

Good Practice

8 CCR 2893, 2534.6

Many laser systems use banks of high-voltage capacitors. Access to these banks shall be carefully marked and controlled, and provisions shall be made to properly maintain grounding and “bleed” charge during maintenance.

F. Class 4 Laser Laboratories

1. Red, mushroom-type, room/area emergency power shutoffs shall be installed in conspicuous locations that are easily accessible from the laboratory entrances. The switches shall be clearly and conspicuously marked with the words “Notice — In Emergency, Push Button to Shut Down Laser.”

ANSI Z136.1 4.3.10.2.1

NFPA 115 6-5.1

2. All laser labs shall be provided with easy egress. Crashbar hardware can be used on outward-swinging doors.

Good Practice

G. Optical Bench Safety

Optical benches shall be secured to prevent substantial movement during an earthquake. This involves anchoring a sturdy frame to the laboratory floor that surrounds and is close to, but not touching, the optical bench (i.e., 1/2-inch clearance between the frame and the bench).

Good Practice

H. Excimer Lasers

1. Halogen gas mixtures shall normally be stored in ventilated gas storage cabinets. All transfer lines and components in contact with halogens shall be made of compatible (nonreactive) materials. Institutional toxic gas program requirements will designate the specific storage quantities allowed (depending on toxicity and other factors).

8 CCR 5191

NFPA 115 8

Conventional ventilated gas storage cabinets will effectively contain the dilute halogen and hydrogen halide in inert gas mixtures used in excimer lasers if the delivery lines are kept bone-dry. Gas storage cabinet hardware allows this to be done using bone-dry nitrogen purge gas.

2. The gas discharge from both the excimer laser and the associated halogen gas storage cabinet shall be connected to an appropriate exhaust ventilation system capable of maintaining an average face velocity of 200 fpm at the cabinet's window opening when the window is fully opened. An alarming airflow meter should be used to monitor and indicate low-flow conditions in the gas cabinet

8 CCR 5191

NFPA 115 8

3. Halogen scrubber devices used on closed (nonventilated) excimer laser systems shall meet appropriate safety standards and shall be preapproved by a campus Industrial Hygienist prior to installation.

8 CCR 5191

NFPA 115 8

I. Laser Generated Air Contaminants (LGACs)

When the beam irradiance exceeds $1,000 \text{ W/cm}^2$, an evaluation shall be performed by an Industrial Hygienist to identify engineering controls for laser generated air contaminants. Places where irradiances exceed $10,000 \text{ W/cm}^2$ shall be enclosed to the maximum extent practical, and be properly ventilated. Exposure to LGACs shall not normally be managed with the use of PPE.

ANSI Z136.1 7.3

Organic materials, including polymers and tissue, will produce plumes containing potentially carcinogenic materials when struck by laser radiation. Polymers will pyrolyze to form toxic gases. Metals and inorganic materials will form fume clouds. These can be treated as common hot-gas air contaminant sources in accordance with ACGIH and ASHRAE criteria. The interiors of the enclosures should be easy to clean/decontaminate. The usefulness of HEPA filtration of the effluent shall also be evaluated when beam irradiances exceed $10,000 \text{ W/cm}^2$.

J. Radio Frequency and Microwave Devices (30 kHz to 300 GHz)

1. Provisions shall be made to protect people from exposures at or above the Maximum Permissible Exposure (MPE) limits. Engineering controls shall be used in lieu of PPE or other administrative controls whenever possible. Shielding shall be designed by or be reviewed by a qualified individual experienced in radio frequency/microwave barrier design.

ANSI C95.1 6.2

Engineering controls, such as shielding and interlocked doors, are preferred over impromptu measures such as stanchions and portable signs, or beacons. Because time-limit controls are framed in six-minute intervals, limiting exposure duration is impractical in most cases.

2. Provisions shall be made to restrict access and to post appropriate warnings for locations where field strengths could exceed the MPE. Appropriate ANSI specification warning signs shall be provided to identify such areas. Signs should be mounted such that they are visible near the doorway and at some distance from it. Signs should not be mounted above doorways, as these can be overlooked.

ANSI C95.1 4.1.1, 4.1.2

3. Barriers and/or cages shall be provided to protect persons from contact with or close proximity to radio frequency electrical currents. These shall be made to prevent exposures exceeding the MPE for radio frequency electrical currents. These provisions shall be designed or reviewed by a qualified individual experienced in radio frequency/microwave design.

ANSI C95.1 6.7

For radio-frequency, electric-current flow limits, the International Commission on Non-Ionizing Radiation Protection's (ICNIRP's) current flow MPE limit is more restrictive, and should be applied. Radio-frequency current flow can begin when two conductors are separated by about a foot because of electric-field interactions

(capacitive coupling), so insulation by itself may not be sufficient. Increased separation distances may be needed in such cases.

K. Power Frequency Fields (60 Hz)

Provisions shall be made to restrict access to locations where electric power frequency magnetic- and electric-field strengths could be hazardous to persons with cardiac pacemakers or other similar electronic medical devices (>1 G and >1000 V/m).

ACGIH - TLV/BEI 2007

Overexposures are extremely unlikely because the exposure limits are so high that few people (except for utility workers) encounter such fields. The carcinogenicity of power-frequency fields is unproven, so no guidance is given concerning this issue.

L. Static Magnetic Fields (Zero Hz)

1. As part of the design process, the static magnetic field in the facility shall be mathematically modeled to identify where pacemaker hazards (> 5 G) and kinetic energy hazards (> 30 G) will exist. Places where excessive whole-body exposures (> 600 G) could occur shall also be identified. If it is determined that shielding is required, an experienced consulting firm should be hired to design the magnetic field shielding.

ACGIH - TLV/BEI 2007

ICNIRP "Guidelines on Limits of Exposure to Static Magnetic Fields"

2. Provisions shall be made to prevent access to places where whole body magnetic fields exceed 600 G. Areas such as hallways, stairways, and offices shall be located where fields are < 5 G to allow completely unrestricted access.

ACGIH - TLV/BEI 2007

ICNIRP "Guidelines on Limits of Exposure to Static Magnetic Fields"

The ACGIH TLV for static magnetic fields is somewhat more restrictive than the ICNIRP standard. The campus needs to determine which exposure criterion to apply.

3. Provisions shall be made to secure and restrict access to places where whole-body magnetic fields exceed 5 G. In some cases, as with MRI systems installed in vans or in isolated buildings, it might be necessary to construct a fence around the facility to ensure that magnetic-field exposures at the perimeter of the fence are below 5 G.

ACGIH - TLV/BEI 2007

A variety of prosthetic devices, makeup, and personal articles can behave in a hazardous manner in stronger fields. A number of medical electronic implants, such as artificial cardiac pacemakers, can malfunction above 5 G.

4. Appropriate ANSI Z535 specification warnings signs shall be provided to identify such areas. Signs should be mounted near the entryways such that they are visible before entering controlled, high-static, magnetic-field areas, and at some distance from them. Signs should not be mounted above doorways, as these can

10. Additional Requirements for Laboratories Using Non-Ionizing Radiation (NIR) Sources, Including Lasers

be overlooked.

5. Provisions should be made for persons to securely store their metal keys, wristwatches, and other ferrous-alloy tools and articles for safekeeping before entering areas where the magnetic field exceeds 30G.

ACGIH - TLV/BEI

ICNIRP "Guidelines on Limits of Exposure to Static Magnetic Fields"

Engineered access controls, such as locked doors, are preferred over stanchions and portable signs. Kinetic energy hazards from even small ferrous items, like razor blades and nails, can cause serious injuries. Larger items, like wrenches, could kill or cause major equipment damage. A field of 50 G has been associated with erasing credit cards and other magnetic media, but it is recommended that such items be kept out of areas in which the magnetic field exceeds 10 G.

6. Appropriate discharge shall be made to direct cryogenic gases from a quenched superconducting magnet to a safe, unoccupied location to avoid exposing people to an oxygen-deficient atmosphere. The issue of preventing oxygen deficiency during a quench condition shall be addressed in the design of locations for superconducting magnets. Doors to locations that may be subjected to gases during a quench shall open outwards to assure they can be opened should the laboratory become pressurized.

29 CFR 1910.134

8 CCR 5144 and 5157

It is estimated that 80 liters of liquid helium (56,000 liters of gas at 1:700 expansion ratio) can be ejected from a magnet Dewar flask in 15 to 30 seconds.

11. ERGONOMICS DESIGN AND LABORATORY SPACES

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B. Integrating Human Factors in Design Projects.....	11-2
C. Laboratory Ergonomic Design Criteria	11-2

A. Background

The physical design and layout of a laboratory where researchers, technicians, engineers, and students work can significantly affect performance, health and safety, product quality, and production efficiency. In the earliest labs, research activities centered on a single table or countertop; this simple layout changed when computers were added for microprocessing, image analysis, and robotic control. Today, technology has advanced to include automated processes for centrifugation, chemical and biological assays, and processing. These advancements, however, have exposed people working inside these high-tech labs to new hazards: cumulative trauma disorders, such as tendonitis, carpal tunnel syndrome, and back disorders. Attention to ergonomic issues can prevent the development of these work-related musculoskeletal disorders, and can result in a more safe and productive workplace.

The term ergonomics means “the study of work.” From a laboratory-ergonomics standpoint, it would involve how people interact with equipment and workstations. Cumulative trauma disorders are signposts that work design is a barrier to a researcher’s performance. To support performance, laboratory facilities and research activities must be designed such that:

- Workstations, scientific products, laboratory layout, optical systems, and displays match the requirements of people in terms of height, reach, and access.
- Material-handling tasks, such as moving carboys and handling compressed gas cylinders, are designed to accommodate differences in strength and body size among workers.
- Barriers to productivity, human performance, and safety are removed by focusing on and understanding lab users’ needs.

Laboratory tasks often require intense eye-to-hand coordination, frequent use of the arms for precision work, manual materials handling, and high demands on visual concentration. In the process of laboratory design, ergonomics needs to be an integral factor. Architects, engineers, and project managers need an understanding of the concepts and resources available to identify and minimize ergonomic risk factors in the laboratory including:

- Static work
- Postures for sitting, and sit-to-stand and standing work stations
- Upper extremity motions, focusing on the shoulder, elbow/forearm, and hand, including grips
- Eye, head, and neck motion
- Repetitive tasks

11. Ergonomics Design and Laboratory Spaces

- Contact stresses
- Manual materials handling tasks

Fitting the work to the worker is at the core of human-factor engineering/ergonomics. This focus recognizes that while people have a wide range of capabilities, they also have a corresponding range of limitations.

Worker comfort directly impacts laboratory research and production. Failure to outfit and set up a laboratory properly can encourage the development of repetitive stress injuries or cumulative trauma disorders. Proper selection and installation of chairs, tables, work surfaces, and equipment can improve worker comfort, safety, productivity, and accuracy.

Use of a systematic approach to the design process can optimize laboratory environments for human use and safety. Human-factor design/ergonomics is most effective when it is an essential part of a good design, not something separate or added on after the fact. It should be integrated into the total design process from start to finish.

B. Integrating Human Factors in Design Projects

1. Consider human factors/ergonomics implications at all stages of the design process, especially the early stages. All design decisions are likely to have some implications for lab and maintenance personnel.
2. Seek assistance from the in-house ergonomics specialist during the design phase.
3. Discuss human-factor design/ergonomics with all who are concerned with or affected by design. The comments of lab users and maintenance personnel are particularly valuable. Maintenance personnel include housekeeping; facilities; and environment, health, and safety specialists (industrial hygienist, radiation safety specialist, etc.). When possible, have a demonstration or sample design available for end users to review and comment on.
4. Incorporate human-factor design/ergonomics requirements into the conceptual design specifications so that their inclusion is insured. Make requirements be as specific as possible, or they may not be adequately considered. Also, make certain human-factor design/ergonomics requirements are budgeted for.
5. If you find that an optimal human-factor design/ergonomics solution is not possible, be sure to carefully consider the impact if a compromise solution is considered.
6. Apply human factors/ergonomics data intelligently and with caution. When data are used, make sure they're applicable to the current problem. Always examine the origins and assumptions of any data.
7. Consider the cost/benefit ratio of human factors/ergonomics recommendations. Even though they may add to initial construction costs, they often result in savings in terms of efficiency and safety.

C. Laboratory Ergonomic Design Criteria

1. Ergonomic design considerations shall be incorporated into laboratory planning,

construction and operation.

- a. The spaces and functions that will require ergonomic features should be specifically determined. Data sources can help identify ergonomic/human-factor design and process-improvement opportunities.
 - Injury and illness data
Injury and illness data can be derived from the OSHA 300 Log and workers' compensation claims data. This information helps to identify where mismatches have occurred in the past.
 - User Feedback
User feedback is gathering information from lab personnel to describe potential lab workstation challenges as seen from the employees and students.
 - Testing and Quality Data
Testing and quality data help to identify which quality faults are derived from human performance problems and then seeing whether there are specific barriers in the existing job or process design that contribute to these problems.
 - Ergonomic Risk-Assessment.
Ergonomic risk-assessments determine what areas have the highest risk exposures.
 - b. A cross-functional team should be formed. The team should address the ergonomic design opportunities identified during the space/function analysis above. Team composition should include multiple disciplines as appropriate.
 - Research staff
 - Supervisor
 - Ergonomist
 - Health and safety professional
 - Architect/engineer
 - Maintenance personnel.
 - c. The team should apply human-factor design principles to develop design solutions to the human performance and safety issues related to particular lab-based ergonomic challenges. During this design process, the team should:
 - Understand the causes of problems and develop and evaluate specific solutions.
 - Agree on the goal: Is it to *eliminate* the identified problem or *limit lab employee exposure* to an acceptable level?
 - Once the goal is established, performance measure(s) can be established.
2. The team should prepare a conceptual design to provide the foundation for the functional design and layout of the space. Equipment requirements, user needs, and performance expectations should be identified, preliminary research and development efforts initiated, and the system specified. User needs and requirements, equipment performance specifications, regulatory constraints, and other factors impacting the lab environment shall be identified before the formal

design process is initiated. Human-factor considerations include the following:

- a. What tasks will be performed by the users?
- b. What conditions will impose peak task loads on lab personnel?
- c. What conditions will tend to fatigue individuals or degrade performance?
- d. Where will tasks be completed (i.e., benches, fume hoods, computers, etc.)?
- e. Will tasks require implementation of specialized safety equipment or environments such as clean rooms, airflow demands, use of hazardous materials?
- f. How many individuals are needed to perform the lab activities under normal and peak conditions?
- g. How will the assigned tasks be distributed among lab personnel?
- h. What information, tools, and equipment must be used by lab personnel to perform their activities?
- i. Will tools and equipment need to be adjustable or mobile to accommodate different workers?
- j. What instrumentation is required at each workstation?
- k. How should this instrumentation be laid out?
- l. What type and quantity of work materials and supplies will need to be stored in the facility? Where will these materials be staged during the receiving/storage process?
- m. Are there any special needs for control/use of hazardous materials or processes?
- n. What lifting, pushing, carrying, and bending tasks will be required? Is there a way to eliminate or reduce the risks associated with these tasks?
- o. Is there any need to address physical size and special accommodations for the lab user population?
- p. Do supplies and equipment need to be physically moved between work areas?

As quantity of material or components increase in size, operators may subject themselves to awkward postures during handling and transportation. When multiple handling occurs, operators may resort to nonneutral postures that may place them more potentially at risk to musculoskeletal trauma. The farther away items are stored from the immediate work area, the more time is lost. Proactive planning to produce flow patterns and to centralize storage locations can reduce ergonomic risks and the extra time and effort needed for awkward handling/transport of equipment and products.

3. Workstations should be tailored to match the human anthropometry (human measurements) to minimize extreme postures, improve task efficiency and provide a safe work environment.
 - a. Workstations should minimize the distances workers must cover to retrieve materials and lab equipment; store items at heights that do not increase

- workers' bending or overhead reaching; position work surfaces at heights that promote neutral postures; ensure identical instrument and component locations throughout areas; and ensure sufficient storage space for materials, and room for multitasking activities.
- b. Computer workstations should be configured so as to promote "neutral" transitions between different phases of work. Issues that should be considered include:
 - Will computers be used during other laboratory activities such as using a microscope or pipetting?
 - What type of work will be done at the computers? Will work be intermittent or prolonged? Can the work be done best by sitting in a chair, stool, or standing?
 - Is there room for the computer on the workbench, or will they be placed on separate workstations?
 - Are computer workstations designed with flexible placement of monitors, keyboards, and mice for a variety of users?
 - Can keyboards be mounted on sliding, adjustable keyboard trays rather than placed upon the work surface, to promote neutral angle of wrists.
 - Do workstations need to be mobile?
 - c. Benches should be designed to promote completion of tasks.
 - Foot room, knee space, overhangs, and/or cutouts should be available at benches for workers to access work surfaces while either sitting or standing.
 - Benches must be sufficiently deep to enable the work to be performed.
 - Rails or other storage shelves mounted below the front edge of benches should be avoided as they can reduce ability to install keyboard trays and other pullout drawers.
 - Bench heights should be adjustable or flexible to accommodate employees of different sizes.
 - A bench's front edges should be rounded rather than sharp cornered to reduce pressure on the forearm.
 - d. Supplies and work materials should be stored to be readily available and accessible.
 - Space should be available for proper segregation of hazardous materials.
 - Heavy items and fluid containers should be located between knee and shoulder level.
 - Pullout shelving and/or lazy Susan devices should be considered for storage-area design.
 - Storage areas should be readily modified to accommodate changes and laboratory practices (for example, modular rolling storage cabinets).
 - e. Fume hoods should be adjustable for researchers of different sizes.
 - Base cabinets should have a knee clearance for seated work (e.g., to accommodate disabled researchers).
 - Angled-glass fronts can improve visibility when working.

APPENDIX A. DEFINITIONS

Aerosols: Colloids of liquid or solid particles suspended in gas.

Biohazardous Materials: Infectious agents, the products of infectious agents, or the components of infectious agents presenting a real or potential risk of injury or illness.

Biosafety Cabinet: A ventilated cabinet which serves as a primary containment device for operations involving biohazard materials. The three classes of biosafety cabinets are described below:

Class I Biosafety Cabinet: The Class I biosafety cabinet is an open-fronted negative-pressured ventilated cabinet with a minimum inward face velocity at the work opening of at least 75 feet per minute. The exhaust air from the cabinet is filtered by a HEPA filter.

Class II Biosafety Cabinet: The Class II biosafety cabinet is an open-fronted, ventilated cabinet. Exhaust air is filtered with a high-efficiency particulate air (HEPA) filter. This cabinet provides HEPA-filtered downward airflow within the workspace. Class II Cabinets are further classified as Type A1, Type A2, Type B1, and Type B2 .

Class II, Type A1 (Formerly Type A) Biosafety Cabinets may have positive-pressure contaminated internal ducts and may exhaust HEPA-filtered air back into the laboratory. 70% of the cabinet air is recirculated and 30% is exhausted, either into the room or outside.

Class II, Type A2 (Formerly Type B3) Biosafety Cabinets have negative-pressure ducts or plenums surrounded by negative-pressure plenums, exhaust HEPA-filtered air through external ducts to space outside the laboratory or to the environment, and have HEPA-filtered downflow air that is a portion of the mixed downflow air and inflow air from a common exhaust plenum. 70% of the cabinet air is recirculated, and 30% is externally vented. Suitable for work with minute quantities of toxic chemicals and radionuclides, if vented to the environment.

Class II, Type B1 Biosafety Cabinets exhaust HEPA filtered air through external ducts to space outside the laboratory, and have HEPA-filtered downflow air. Thirty percent of the cabinet air is recirculated, and 70% is externally vented. Suitable for work with minute quantities of toxic chemicals and radionuclides.

Class II, Type B2 Biosafety Cabinets exhaust HEPA-filtered air through external ducts to space outside the laboratory, and have HEPA-filtered air downflow air drawn in from the laboratory or outside air. One hundred percent of the cabinet air is externally vented without recirculation. Suitable for work with minute quantities of toxic chemicals and radionuclides.

Class III Biosafety Cabinet: The Class III biosafety cabinet is a totally enclosed, negative-pressure ventilated cabinet of gas-tight construction. Operations within the Class III cabinet are conducted through protective gloves. Supply

air is drawn into the cabinet through high-efficiency particulate air filters. Exhaust air is filtered by two high-efficiency particulate air filters placed in series, or by high-efficiency particulate air filtration and incineration, and discharged to the outdoor environment without recirculation.

Biosafety Level: Biosafety levels consist of laboratory practices and techniques, safety equipment, and a laboratory facility appropriate for the operations performed and for the hazard posed by the particular biohazard material. The Centers for Disease Control (CDC) and the National Institute of Health (NIH) define the four biosafety levels in the publication, *Biosafety in Microbiological and Biomedical Laboratories*, and recommend biosafety levels for particular pathogenic microorganisms.

Boiling Point: The temperature at which the vapor pressure of a liquid equals the surrounding atmospheric pressure. For purposes of defining the boiling point, atmospheric pressure shall be considered to be 14.7 psia* (760 mm Hg).

Compressed Gas: A gas or mixture of gases having an absolute pressure exceeding 40 psi at 70°F (21°C) in a container; a gas or mixture of gases having an absolute pressure exceeding 104 psi in a container at 130°F (54°C), regardless of the pressure at 70°F (21°C), or both; or a liquid having a vapor pressure exceeding 40 psi at 100°F (38°C) as determined by UFC Standard No. 9-5.

Containment: The combination of personal practices, procedures, safety equipment, laboratory design, and engineering features to minimize the exposure of workers to hazardous or potentially hazardous agents.

Cryogenic Fluids (“Cryogen”): Elements and compounds that vaporize at temperatures well below room temperature. Most common cryogenics have a normal boiling point below approximately 120 K. Helium-4 (4.2 K), hydrogen (20 K), nitrogen (77 K), oxygen (90 K), and methane (112 K) [normal boiling point temperatures in parentheses] are examples of cryogenics.

Decontamination: Removal or destruction of infectious agents; removal or neutralization of toxic agents.

Flammable or Combustible Liquids (Definitions from NFPA 30, Chapters 1–7)

Flammable Liquid: Any liquid that has a closed-cup flash point below 100°F (37.8°C).

Class I Liquid: Any liquid that has a closed-cup flash point below 100°F (37.8°C) and a Reid vapor pressure not exceeding 40 psia at 100°F (37.8°C).

Class IA Liquids include those liquids that have flash points below 73°F (22.8°C), and boiling points below 100°F (37.8°C).

Class IB Liquids include those liquids that have flash points below 73°F (22.8°C), and boiling points at or above 100°F (37.8°C).

Class IC Liquids include those liquids that have flash points at or above 73°F (22.8°C), but below 100°F (37.8°C).

Combustible Liquid: A combustible liquid shall be defined as any liquid that has a closed-cup flash point at or above 100°F (37.8°C).

Class II Liquid: Any liquid that has a flash point at or above 100°F (37.8°C), and below 140°F (60°C).

Class IIIA Liquid: Any liquid that has a flash point at or above 140°F (60°C), but below 200°F (93°C).

Class IIIB Liquid: Any liquid that has a flash point at or above 200°F (93°C).

Flammable Anesthetic Gas: A compressed gas that is flammable and administered as an anesthetic including cyclopropane, divinyl ether, ethyl chloride, ethyl ether, and ethylene.

Flash Point: The minimum temperature of a liquid at which sufficient vapor is given off to form an ignitable mixture with air, near the surface of the liquid, or within the vessel used.

Fume Hood: A device enclosed on three sides, as well as the top and bottom, with an adjustable sash or fixed partial enclosure on the remaining side. They are designed, constructed, and maintained so as to draw air inward by means of mechanical ventilation, and so that any operation involving hazardous materials within the enclosure does not require the insertion of any portion of a person's body other than the hands and arms into the work area. (Note: Laboratory fume hoods prevent toxic, flammable, or noxious vapors from entering the laboratory; present a physical barrier from chemical reactions; and serve to contain accidental spills).

HIV/HBV Research Facility: A laboratory producing or using research-laboratory scale amounts of HIV or HBV. Research laboratories may produce high concentrations of HIV or HBV, but not in the volume found in production facilities.

Laser Hazard Class: The relative hazard of a given laser or laser system as specified in the ANSI Z136.1 Standard. Present laser Classes are 1, 2, 3a, 3b, and 4. Generally, only Class 3b and 4 lasers present hazards sufficient to require specialty laboratory designs.

Local Exhaust Ventilation: Exhaust applied close to a source of air contaminants to prevent the migration of those contaminants into the breathing zones of people. It is often used for control of exposures to hazardous chemicals when the apparatus is not appropriate for placing in a fume hood. These applications shall be evaluated by EH&S for exposure control, and possible impacts on other ventilation systems.

Maximum Permissible Exposure (MPE): The level of any radiation to which a person may be exposed without hazardous effect or adverse biological changes in the organ(s) of concern. The MPE is normally expressed at a specific energy/frequency/wavelength and a defined exposure duration.

Microwave Radiation: That portion of radiofrequency energy consisting of radiation with frequencies between 300 GHz and 300 MHz.

Nonflammable Medical Gas: A compressed gas, such as oxygen or nitrous oxide, which is nonflammable, but a strong oxidizer, and used for therapeutic purposes.

Non-ionizing Radiation (NIR): All electromagnetic radiation with photon energy less than 12.4 eV (> 100 nm wavelength) and electric or magnetic fields. Examples are: Lasers, nuclear magnetic resonance (NMR), microwave devices, radio-frequency devices, high-intensity ultraviolet (UV) and infrared sources, and high-powered magnets. It is usually assumed that energy at frequencies below 300 MHz exists as discrete electric and magnetic fields rather than as electromagnetic radiation.

Operational Volumetric Flow Rate: The volumetric flow rate of supply air ventilation delivered to meet the minimum airflow requirements of a laboratory space for the comfort of the typical number of occupants, plus sufficient volume to maintain negative pressurization of the space. The exhaust volumetric flow rate will be variable in labs equipped with variable air volume (VAV) hoods.

Optical Radiation: Any radiation whose wavelength is between 100 nm and 1 mm. Lasers normally fall into this area.

Power-Frequency Field: Any field whose frequency is between 3 kHz and 1 Hz.

Pressure Vessel: Storage tank or vessel that has been designed to operate at pressures above 15 psig.

Radio Frequency Energy (Radiation): Any energy with frequencies in the range between 3 kHz and 300 GHz.

Safety Showers and Eyewashes

Emergency Shower or Deluge Shower: A unit consisting of a shower head controlled by a stay-open valve that enables a user to have water cascading over the entire body.

Eyewash: A device used to irrigate and flush the eyes.

Combination Unit: An interconnected assembly of an eyewash and safety shower, supplied by a single plumbed source.

Static Magnetic Fields: Direct current (zero Hz) magnetic fields. Magnetic flux density (often called magnetic field strength) is expressed in A/m, Gauss (G), or Tesla (T). The units are related as $1 \text{ A/m} = 12.6 \text{ mG} = 1.26 \text{ } \mu\text{T}$.

Tepid Water: Water which is moderately warm or lukewarm.

Threshold Limit Value/Ceiling (TLV-C): The exposure limit that should not be exceeded, even for an instant.

Threshold Limit Value/Time Weighted Average (TLV-TWA): The time weighted average exposure allowed for an 8-hour workday and a 40-hour workweek.

Toxic Material: Classes of toxicity include “acutely” and “chronically toxic.” Included within the class of materials that exhibit chronic toxicity are carcinogens, mutagens, and teratogens.

Acutely Toxic Material: A material for which the lethal exposure levels fall within the ranges shown in the table below:

Acute Toxicity Hazard Level					
Hazard Level	Toxicity Rating	Oral LD ₅₀ (Rats, per kg)	Skin Contact LD ₅₀ (Rabbits, per kg)	Inhalation LC ₅₀ (Rats, ppm for 1 hr.)	Inhalation LC ₅₀ (Rats, mg/m ³ for 1 hr.)
High	Highly toxic	< 50 mg	< 200 mg	< 200	< 2,000
Medium	Moderately toxic	50 – 500 mg	200 mg – 1g	200 – 2,000	2,000 – 20,000
Low	Slightly toxic	500 mg - 5 g	1- 5 g	2,000 - 20,000	20,000 to 200,000

Carcinogen (definitions from *Prudent Practices in the Laboratory*): Materials considered to be carcinogens include substances regulated by OSHA as carcinogenic; substances listed as “known to be a carcinogen” in the latest *Annual Report on Carcinogens* issued by the National Toxicology Program (U.S. DHHS, NTP); substances listed under Group 1 (“carcinogenic to humans”) by the International Agency for Research on Cancer (IARC); and other similar sources.

Toxic Material: A material that produces a lethal dose or a lethal concentration within any of the following categories:

- A chemical or substance that has a median lethal dose (LD₅₀) of more than 50 milligrams but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats of between 200 and 300 grams each.
- A chemical or substance that has a median lethal dose (LD₅₀) of more than 200 milligrams but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact with the bare skin of albino rabbits of between 2 and 3 kilograms each for 24 hours, or less if death occurs within 24 hours.
- A chemical or substance that has a median lethal concentration (LC₅₀) in air more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than two milligrams per liter but not more than 20 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour, or less if death occurs within one hour, to albino rats of 200 and 300 grams each.

Highly Toxic Material: Material that produces a lethal dose or lethal concentration that falls within any of the following categories:

- A chemical that has a median lethal dose (LD₅₀) of 50 milligrams or less per kilogram of body mass (mg/kg) when administered orally to albino rats of between 200 and 300 grams each.

Appendix A. Definitions

- A chemical that has a median LD50 of 200 mg/kg when administered by continuous contact with the bare skin of albino rabbits of between 2 and 3 kilograms each for 24 hours, or less if death occurs within 24 hours.
- A chemical that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour, or less if death occurs within one hour, to albino rats between 200 and 300 grams each.

NOTE: Mixtures of these materials with ordinary materials, such as water, may result in an unwarranted classification of a material as highly toxic. While this system is basically simple in application, any hazard evaluation that is required for the precise categorization of this type of material shall be performed by experienced, technically competent persons.

Vapor Pressure: The pressure, often measured in psia, exerted by a liquid.

APPENDIX B. REFERENCES

“CCR” means California Code of Regulations; these are available at:
<http://www.calregs.com/> . (Note: California Code of Regulations (CCR) was once known as California Administrative Code (CAC).)

“CFR” means Code of Federal Regulations; these are available at:
<http://www.access.gpo.gov/nara/cfr/>.

Occupational safety and health regulations are available at:
<http://www.dir.ca.gov/samples/search/query.htm> for Cal/OSHA regulations and
[http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARD
S&p_toc_level=0&p_keyvalue=](http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARD_S&p_toc_level=0&p_keyvalue=) for OSHA regulations.

“USC” means United States Code.

The California Building, Electrical, Mechanical, Plumbing, and Fire Codes are all parts of 24 CCR. 24 CCR is not available online. It can be ordered from Barclays Law Publishers, P. O. Box 3066, South San Francisco, CA 94083, 800/888-3600 or on the LAWDESK CD from West Group, 610 Opperman Drive, Eagan, MN 55123, 651/687-7000.

In addition to references cited in the text, the list below contains additional references that are presented in the interest of completeness:

- 8 CCR, Division 1, Chapter 4, Subchapter 5 Electrical Safety Orders
- 8 CCR 2299 - 2599, Low-Voltage Electrical Safety Orders
- 8 CCR 2700 - 2974, High-Voltage Electrical Safety Orders
- 8 CCR, Division 1, Chapter 4, Subchapter 7 General Industrial Safety Orders
- 8 CCR 3241, Live Loads
- 8 CCR 4650, Storage, Handling, and Use of Cylinders
- 8 CCR 5143, General Requirements for Mechanical Ventilation Systems
- 8 CCR 5144(d)(2)(C), Respiratory Protection, definition of oxygen deficient atmosphere.
- 8 CCR 5154.1, Ventilation Requirements for Laboratory-Type Hood Operations.
- 8 CCR 5154.2, Ventilation Requirements for Biological Safety Cabinets.
- 8 CCR 5157, Permit-Required Confined Spaces.
- 8 CCR 5162, Emergency Eyewash and Shower Equipment.
- 8 CCR 5191, Occupational Exposure to Hazardous Chemicals in Laboratories.
- 8 CCR 5193, Bloodborne Pathogens.
- 8 CCR 5209, Carcinogens.
- 8 CCR 5217(i), Formaldehyde

Appendix B. References

- 8 CCR 5533, Design, Construction, and Capacity of Storage Cabinets
- 10 CFR, Nuclear Regulatory Commission regulations:
- 10 CFR 20.1201, Occupational Dose Limits
- 10 CFR 20.1301, Radiation Dose Limits for Individual Members of the Public
- 10 CFR, Parts 20 and 35
- 17.CCR, Division 1, Chapter 5, Subchapter 4 Radiation
- 19 CCR, Division 2, Chapter 4.5, Article 5, 2755.2 Hazard Review
- 22 CCR, Social Security
- 24 CCR, California Referenced Standards Code:
- 24 CCR, Part 2, California Building Code
- 24 CCR, Part 2, Chapter 10 (Egress)
- 24 CCR, Part 2, Chapter 31C Radiation, Section 3104C; Medical Therapeutic X-Ray Installations.
- 24 CCR, Part 3, California Electrical Code
- 24 CCR, Part 4, California Mechanical Code
- 24 CCR, Part 5, California Plumbing Code
- 24 CCR, Part 9, California Fire Code
- 24 CCR, Part 12, Chapter 31C, Radiation Shielding Standards, Standard 12-31C-1, Section 12-31C-101
- 24 CCR, Part 12, Chapter 31C, Radiation, Sections 3101C- 3104C
- 29 CFR 1910, Federal OSHA Occupational Safety and Health Standards
- 29 CFR 1910.134(b) Respiratory protection, definition of oxygen deficient atmosphere
- 29 CFR 1910.146, Permit-required confined spaces
- 29 CFR 1910.151(c), Requirements for emergency eyewashes and showers *plus* interpretation letters: http://www.osha-slc.gov:80/OshDoc/Interp_data/119940930.html (September 30, 1994) , http://www.osha-slc.gov/OshDoc/Interp_data/119920720C.html (July 20, 1992)
- 29 CFR, 1910 Subpart S, Electrical
- 29 CFR 1910.1030 Bloodborne pathogens
- 29 CFR 1910.1048, Formaldehyde
- 29 CFR 1910.1450, Occupational exposure to hazardous chemicals in laboratories
- 29 CFR 1910.1450, Appendix A, National Research Council Recommendations Concerning Chemical Hygiene in Laboratories (*Prudent Practices in the Laboratory*)

- 40 CFR Part 191, Environmental radiation protection standards for management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes
- American Conference of Governmental Industrial Hygienists (ACGIH), *Industrial Ventilation: A Manual of Recommended Practice*, American Conference of Governmental Industrial Hygienists, Cincinnati, OH (2007 or latest ed.)
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- Title I, "Employment," Sec. 101, "Definitions," 42 USC 12111 9(A).
 - Title III, "Public Accommodations and Services Operated by Private Entities," Sec. 303, "New Construction and Alterations in Public Accommodations and Commercial Facilities," 42 USC 12183.
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- National Fire Protection Association, NFPA Handbook 70, *National Electrical Code® Handbook*. Quincy, MA (latest ed.)
- National Fire Protection Association, NFPA 77, *Recommended Practice on Static Electricity*. Quincy, MA (latest ed.)
- National Fire Protection Association, NFPA 80, *Standard for Fire Doors, Fire Windows*. Quincy, MA (latest ed.)
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