

INTRODUCTION

Purpose

The University of Houston (UH) has a continuing need to modernize and upgrade its facilities to support future growth and operations. The resulting construction projects often have significant health and life safety requirements due to regulatory oversight. Since these requirements can impact the design of a project, Environmental Health and Life Safety (EHLS) prepared the EHLS Laboratory Design Guide to aid the campus community with planning and design issues. EHLS believes that the Guide, in conjunction with EHLS plan review and consultation, improves EHLS design efficiency and minimizes changes.

Application

The Guide is a resource document for use by faculty, staff, and design professionals during the planning and early design phases of a project. The Guide applies to construction projects for all UH facilities including leased properties.

Format of Guide

The Guide is formatted to address laboratory design issues pertinent to *General Laboratories* (e.g., chemical laboratories) in Section 1 with additional requirements for *Radioactive Materials Laboratories* and *Biosafety Level 2 Laboratories* presented in Sections 2 and 3 respectively.

Within the sections, specific design criteria are provided. Comments are included under the specific design criterion to give the user the rationale behind the design feature.

References

References include regulations (e.g., NFPA Fire Code), consensus standards (e.g., ANSI/ASHRAE/AAALAC), and good practices. Good practices stem from industry standards and/or the judgment/knowledge of UH EHLS professionals.

Design criteria are designated in the following ways:

Shall and Must: Mandated by applicable regulation(s).

- *The user of the Guide is required to include the design feature.*
- Based on well-established consensus standards/guidelines.
“Must” is used to reflect a UH requirement, although not required by a regulation.

Should: Advisory in nature based on good engineering and safety practices.

- *It is left to the discretion of the user of the Guide to include the design feature.*

Limitations of the Guide

The EHLS Laboratory Design Guide is not all-inclusive. It does not cover all regulatory requirements nor does it cover all design situations. It is important to note that *use practices* and adjacent occupancy considerations must be considered during the design process, as they can directly influence how the laboratory will be designed (e.g., how hazardous materials are used impacts how they are stored, which is a design issue) Adjacent occupancy will affect the strength of magnets proposed to be used and this has to be taken into design considerations. In all cases, EHLS should be consulted on questions regarding health, safety, fire and environment.

ACKNOWLEDGEMENT

The majority of this document was adapted from the NFPA Fire Code and ANSI Standards.

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VENTILATION**TABLE OF CONTENTS**

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A. Regulations, Standards and References***Regulations:***

Code of Federal Regulation (CFR) 10, Parts 20 and 35

National Fire Protection Association (NFPA) 101/Life Safety Code (current edition)

National Fire Protection Association (NFPA) Handbook 45 (current edition)

Standard on Fire Protection for Laboratories Using Chemicals

National Fire Protection Association (NFPA) Handbook 99

Standard for Health Care Facilities

National Fire Protection Association (NFPA) 801 Facilities Handling Radioactive Material

Consensus Standards and References:

American National Standards Institute (ANSI), Z358.1

Emergency Eyewash and Shower Equipment

American National Standard for Laboratory Ventilation (ANSI/AIHA Z9.5)

American National Standard for Thermal Environmental Conditions for Human Occupancy (ANSI/ASHRAE 55-1992)

American Conference of Government Industrial Hygienists Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices (ACGIH)

ANSI Z136.1, American National Standard for Safe Use of Lasers

Texas Accessibility Standard

“Safe Handling of Radionuclides”, International Atomic Energy Agency, Safety Series No. 1, (1973 ed. Is still current as of 1999) (IAEA)

B. Scope

The requirements of this Guide apply to any UH System, Campus Energy Research Park, or component laboratory space in which hazardous materials are used, handled or stored.

C. General Ventilation Considerations

- 1. The lab should have mechanically generated supply air and exhaust air. All lab rooms shall use 100% outside air and exhaust to the outside. There shall be no recirculated air from the fume hood or laboratory space.**

Good Practice per UH EHLS
Prudent Practices in the Laboratory
NFPA 45, Chapter 6-4.1
ANSI/AIHA Z9.5, 4.10.3
ANSI/ASHRAE

- 1.1 Adjacent support offices may have recirculated air.**
- 1.2 All newly constructed or renovated laboratory spaces must have a third party Associated Air Balance and Certification (AABC) certified air balance performed.**

The air balance of the lab must not be adjusted unless the department of Environmental Health and Life Safety (EHLS) has been notified of such changes.

- 2. Mechanical climate control shall provide adequate temperature and humidity thresholds to meet Uniform Mechanical Controls and International Mechanical Controls as required.**

Uniform Mechanical Code

- Per ASHRAE 55-1992, comfortable temperature range are defined as follows:**

Winter: 69-76 °F (at 35% RH); Summer: 73-79 °F (at 60% RH)

- 3. Additional equipment loads must be considered in the overall CFM design of lab/support offices.**
 - 3.1 Labs shall not have open windows as this will change the air balance and create a lab directional airflow integrity deficiency.**
 - 3.2 Lab casework or other laboratory equipment must not impeded airflow throughout the lab. Air flow should be laminar and conducive to adequate air change rate.**

ASHRAE 55-1992

Many supply diffusers and room exhaust room openings are located along laboratory walls. Storage of boxes near these openings may obstruct the circulation of air and supply or exhaust air functioning.

4. General laboratories shall have a minimum of 10-air changes/hour.

Laboratories within animal holding rooms must meet AAALAC standards. Design and Construction of Inside Storage Rooms, General Industry Standard 29 CFR 1910. 106, OSHA 2206, Nov. 7, 1987 (OSHA, 1987).

ASHRAE Handbook, Chapter 13

International Mechanical Code

5. Laboratories must be maintained under negative pressure in relation to the corridor or other less hazardous areas. Clean rooms requiring positive pressure should have entry vestibules provided with door-closing mechanisms so that both doors are not open at the same time. Consult with EHLS Fire Marshal for design details.

ANSI/AIHA Z9.5 – 1992, 4.11.4-4.11.5

NFPA 45

As a general rule, directional airflow should be from areas of low hazard to a high hazard. Clean room or sterile room directional airflow shall be positive to the adjacent corridor or vestibules.

If there is a desire to modify to achieve sustainable initiatives or LEED certification those modifications must be approved by EHLS and the core team or the authority having jurisdiction.

6. Where appropriate, general ventilation systems should be designed such that, in the event of an accident, they cannot be shut down.

NFPA 45

6.1 The transfer of duct work shall not be designed within laboratory spaces. All duct work shall be active, not passive in nature.

NFPA 45

7. The air velocity volume in each duct should be sufficient to prevent condensation or liquid or condensable solids on the walls of the ducts.

NFPA 45

- 8. Fume hoods should not be the sole means of room air exhaust. General room exhaust outlets shall be provided where necessary to maintain minimum air change rates and temperature control.**

ASHRAE 55-1992

- 9. Operable windows shall be prohibited in new lab buildings and should not be used on modifications to existing buildings.**

Good Practice per UH EHLS

- 10. Local exhaust ventilation – point of use exhaust devices (e.g., “snorkels” or “elephant trunks”), other than fume hoods, shall be designed to adequately control exposures to hazardous – materials (chemicals). An exhausted manifold or manifolds with connections to local exhaust may be provided as needed to collect potentially hazardous exhausts from gas chromatographs, vacuum pumps, excimer lasers, or other equipment which can produce potentially hazardous air pollutants. The containment 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, 23th edition, or latest edition

Enclosure minimizes the volume of airflow needed to attain any designed degree of containment control. This reduces fan size, motor horsepower, make up air volume, and make up air conditioning costs.

- 11. Fume hoods, exhaust fans, and electric starters shall be labeled to provide lab designation and which fan or ventilation system they are connected to.**

Good Practice per UH EHLS
NFPA 45

- 12. No laboratory ventilation system ductwork shall be internally insulated. Sounds baffle or external acoustical insulation at the source should be used for noise control but designed so as not to provide static pressure drop and create condensables.**

NFPA 45

- 13. Duct work design shall provide adequate static pressure for both constant volume and/or manifolded systems.**

D. Negative Pressurization**1. Airflow shall be from low hazard to high hazard areas.**

Good Practice per UH EHLS
CDC-NIH Biosafety in Microbiological and Biomedical Laboratories

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

It is recommended that laboratories should contain a fully integrated laboratory control system to control the 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.

2. An adequate supply of make-up air (90% of exhaust) should be provided to the lab.

Good Practice per UH EHLS

3. An air lock or vestibule may be necessary in certain high-hazard laboratories to minimize the volume of supply air required for negative pressurization control. These doors should be provided with interlocks so that both doors cannot open at the same time.

Good Practice per UH EHLS

4. A corridor should not be used as a plenum.**4.1 The above ceiling space within a laboratory must not be used as a plenum.**

NFPA 45

5. Lab tracking DDC controlled (phoenix) exhaust valves shall fail open. Do not design airflow.**E. Supply Air Arrangements****1. Make-up air should be laminar in design and introduced at 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. Supply registers shall not be bidirectional but laminar in order not to produce cross drafting.**

NFPA 99, Chapter 5-4.3.2
NFPA 45, Chapter 6-3.4 and 6-9.1
NIH Design Policy and Guidelines, Research Laboratory, 1996, D.7.7
ANSI Z9.5-2003

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

- 2. Make-up 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 (laminar flow.)**

NFPA 45

- 3. Cabinetry or other structures or equipment should not block or reduce effectiveness of supply or exhaust air.**

Good Practice per UH EHLS

- 4. 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.**

Good Practice per UH EHLS
ASHRAE Standard 62
Uniform Mechanical Code

F. Fume Hood Location

- 1. Fume hoods should be located away from activities or facilities, which produce air currents or turbulence. Locate away from high traffic areas, air supply diffusers, doors.**

NFPA 99, Chapter 5-4.3.2
NFPA 45, Chapter 6-3.4 and 6-9.1

Air turbulence affects the capability of hoods to exhaust contaminated air. Eddies are created by people passing by and by other sources of air currents.

- 2. Fume hoods should not be located adjacent to a single means of egress. Recommend that hoods be located more than 10 feet from any door or doorway.**

NFPA 45, Chapter 6-9.2
NFPA 45, Chapter 3-4.1(d)
NFPA 99, Chapter 5-4.3.2
ANSI/AIHA Z9.5, 5.4

A fire hazard or chemical release incident, both of which may start in a fume hood, can block an exit rendering it impassable. A fire or explosion in a fume hood located adjacent to a path of egress could trap someone in the lab.

- 3. Fume hood openings should not be located opposite workstations where personnel will spend much of their working day, such as desks or microscope benches.**

NFPA 45, Chapter 6-9.3

Materials splattered or forced out of a hood could injure a person seated across from the hood.

- 4. An emergency eyewash/shower station shall be within 10 seconds or 55 feet travel distance away of each work area.**

ANSI Z358.1

Per ANSI Z358.1, the requirement for an eyewash/shower is triggered when an employee may be exposed to substances, which are “corrosive or severely irritating to the skin or which are toxic by skin absorption” during normal operations or foreseeable emergencies. Fume hoods are assumed to contain such substances; hence UH interprets this regulation to mean that emergency eyewash/shower station shall be within 10 seconds or 55 feet travel distance away from work areas.

- 5. An ADA emergency eyewash/shower shall be within 10 seconds or 55 feet travel distance away from an ADA work area (minimally one ADA hood per laboratory floor).**

Texas Accessibility Standard (TAS)
Disable Accessibility Guidebook
ANSI

The location of at least ADA hood per floor enable disabled individuals to conduct their research without having to transport chemicals, etc., in elevators.

G. Approved Equipment

- 1. All fume hoods shall meet the requirements of NFPA 45, Standard on Fire Protection for Laboratories Using Chemicals. EHLS must approve the use of low flow hoods or low flow concept hoods.**

H. Fume Hood and Local Exhaust Ventilation Selection/Types

1. General: Factors to consider when selecting a fume hood:

- a. Room size (length x width x height)
- b. Number of rooms air changes
- c. Lab heat load
- d. Types of material used
- e. Linear feet of hood needed based on:
 - ✓ Number of users/hood
 - ✓ Frequency of use
 - ✓ % of time working at hood
 - ✓ Size of apparatus to be used in hood, etc.

A facility designed for intensive chemical use should have at least 2.5 linear feet of hood space per occupant.

Good Practice per UH EHLS

Evaluating the operational and research needs of the users will ensure that the appropriate type and number of hoods is integrated into the laboratory.

2. Constant Volume Hoods

These hoods permit a stable air balance between the ventilation systems and exhaust by incorporating a bypass feature. If bypass is 100%, this allows a constant volume of air to be exhausted through the hood regardless of sash position.

3. Variable Air Volume (VAV) Fume Hoods

These hoods maintain constant face velocities by varying exhaust volumes in response to changes in sash position. Because the only amount of air needed to maintain the specified face velocity is pulled from the room, significant energy savings are possible when the sash is closed. However, since these hoods cost more upfront and require more maintenance, effective sash management (e.g., pull sash closed when not using hood) is necessary.

Good Practice per UH EHLS

4. Supply or Auxiliary Air Hoods

These hoods are not permitted unless an exception is granted by EHLS.

It is very difficult to keep the air supply and exhaust of supply hoods properly balanced. In addition the supply air is interperate 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.

- 5. Ductless Fume Hoods: Portable non-ducted fume hoods are generally not permitted, however, a portable hood may be used for limited applications (e.g., used inside of an existing hood for a special application, such as odor control). Such applications must be reviewed and approved EHLS on a case-by-case basis.**

ANSI/AIHA Z9.5, 5.16

Portable hoods often do not meet the regulatory airflow requirements. Filters used with these units must be changed frequently and vary in filtration effectiveness from chemical to chemical.

6. Perchloric/Hot Acid Hoods:

- a. Heated Perchloric acid shall only be used in a laboratory hood specifically designed for its use and identified as "For Perchloric Acid Operations." (Exception: Hoods not specifically designed for use with Perchloric acid shall be permitted to be used where the vapors are trapped and scrubbed before they are released into the hood).

NFPA 45, Chapter 6-11.1

Heated Perchloric acid will give off vapors that can condense and form explosive perchlorates. Limited quantities of Perchloric acid vapor can be kept from condensing in laboratory exhaust systems by trapping and scrubbing the vapors at the point of origin.

- b. Perchloric acid hoods and exhaust ductwork shall be constructed of materials that are acid resistant, nonreactive, and impervious to Perchloric acid.

NFPA 45, Chapter 6-11.2
ANSI/AIHA Z9.5

- c. The exhaust fan should be acid resistant and spark-resistant. The exhaust fan motor should not be located within the ductwork. Drive belts should not be located within the ductwork.

NFPA 45, Chapter 6-11.3

- d. Ductwork for Perchloric 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. Horizontal runs shall be as short as possible, with no sharp turns or bends. The ductwork shall provide a positive drainage slope back into the hood. Duct shall consist of sealed sections. Flexible connectors shall not be used.

NFPA 45, Chapter 6-11.4

- e. Sealants, gaskets, and lubricants used with Perchloric acid hoods, duct work, and exhaust systems shall be acid resistant and nonreactive with Perchloric acid.

NFPA 45, Chapter 6-11.5
ANSI/AIHA Z9.5

- f. A water spray system shall be provided for washing down the hood interior behind the baffle and the entire exhaust system. The hood work surface shall be watertight with a minimum depression of 13 mm (½ inch) 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
ANSI/AIHA Z9.5

Perchloric acid is a widely used reagent known to produce flammable or explosive reaction products; hence, the need to have wash down capabilities after each use to remove residues. A watertight surface will contain any chemical spills or leaks from leaking to underneath hood.

- g. Spray wash-down 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 shall consist of sealed sections and no flexible connectors shall be used.

NFPA 45, Chapter 6-11.4

- h. The hood surface should have an all-welded construction and have accessible rounded corners for cleaning ease.

NFPA 45
Access for cleaning is an important design feature

- i. The hood baffle shall be removable for inspection and cleaning.

NFPA 45, Chapter 6-11.7

- j. Each Perchloric acid hood must have an individually designated duct and exhaust system.

ANSI/AIHA Z9.5

7. Radioactive Material Use

- a. Laboratory hoods in which radioactive materials are handled shall be identified with the radiation hazard symbol.

NFPA, Chapter A-6-12.1

- b. Fume hoods intended for use with radioactive isotopes must be constructed of stainless steel or other materials that will not be corroded by the chemicals used in the hood.

NCRP Report #8
NFPA 99, Chapter 5-4.3.3
DOHS2010

- c. The interior of all radioisotope hoods must have covered corners to facilitate decontamination.

NFPA 99, Chapter 5-4.3.3
DOHS2010
IAEA, Safe Handling of Radionuclides

Cracks and crevices are difficult to decontaminate.

- d. The hood exhaust may require filtration by HEPA or Charcoal HEPA filters. Where such is the likelihood, the hood must have a bag-out plenum for mounting such filters and fan capacity for proper operation of the hood with the filter installed. The most appropriate location for the plenum is near the exhaust port of the fume hood (i.e., proximal to the hood).

NFPA 99, Chapter 5-4.3.3
DOHS2010
IAEA, Safe Handling of Radionuclides

- e. Hoods used for radioactivity should have sashes with horizontal sliding glass panels mounted in a vertical sash.

NFPA 99, Chapter 5-4.3.3
DOHS2010
10 CFR 20: Appendix B
IAEA, Safe Handling of Radionuclides

- f. The cabinet on which the hood is installed shall be adequate to support shielding for the radioactive materials to be used therein.

NFPA 99, Chapter 5-4.3.3
DOHS2010
10 CFR 20: Appendix B
IAEA, Safe Handling of Radionuclides

- g. In general, glove boxes with HEPA filtered exhausts shall be provided for operations involving unsealed radioactive material that emit alpha particles. Consults with the Radiation Safety Program for specific requirements.

NFPA 99, Chapter 5-4.3.3
DOHS2010
10 CFR 20: Appendix B
IAEA, Safe Handling of Radionuclides

- 8. American with Disabilities Act (ADA) Hoods:** Must consult with UH's ADA Compliance Office regarding the number of lab hoods to install in facilities which are accessible to and usable by individuals with disabilities – recommend minimally one ADA hood per laboratory floor. These hoods must provide appropriate work surface heights, knee clearances, reach to controls, etc., to individuals in wheelchairs.

Texas Accessibility Standard (TAS)
Disability Accessibility Guidebook

The location of at least one ADA hood per floor will enable disabled individuals to conduct their research without having to transport chemicals, etc., in elevators.

9. Walk-in Fume Hoods; these hoods must meet the type, design, and construction requirements of ANSI/AIHA Z9.5-1992, 5.13.

ANSI/AIHA Z9.5

10. Special Purpose Hoods: These hoods include enclosures for operations for which other types of hoods are not suitable (e.g., enclosures for analytical balances, histology processing machines, special mixing stations, evaporation racks). These hoods must be designed per ANSI Z9.2 and the Industrial Ventilation manual.

ANSI/AIHA Z9.5

Industrial Ventilation – A Manual of Recommended Practice (ACGIH)

I. Fume Hood Labeling

1. Laboratory hoods and special local exhaust ventilation systems (SLEV) shall be labeled to indicate intended use (e.g., “Perchloric Acid Hood”).

NFPA 45, Chapter 6-12.1

2. A label must be affixed to each hood containing the following information from the last inspection:
 - a. Verification due date
 - b. Average face velocity
 - c. Inspector’s initials

NFPA 45, Chapter 6-12.2 (NOTE: This code sites slightly different information for the label. UH determined it was appropriate to create a label with the above information).

J. Fume Hood Construction, Installation & Performance

1. Fume hoods designed for use must meet the intent of the chemicals to be used. Hoods that will exhaust corrosive materials, acids, etc. shall be designed for the intended use.

2. New hoods can be mounted above a chemical storage cabinet, provided that the cabinet meets the NFPA 101 Life Safety Code requirements for construction.

Good Practice per UH EHLS

Recommend that solvent storage not be located under the laboratory fume hood as this location is where fires are most likely to occur in laboratories.

3. Type 316 stainless steel should be used for all parts of the fume hood system ventilation duct as long as compatibility is maintained.

Good Practice per UH EHLS

This material affords good, general corrosion, impact and vibration resistance.

4. Fume hood interior surfaces shall be constructed of corrosion resistant, non-porous, non-combustible materials such as type 316 stainless steel, and should be smooth and impermeable with rounded corners. These materials shall have a flame spread index of 25 or less when tested in accordance with NFPA method 255, Standard Method of Test of Surface Burning Characteristics of Building Materials.

NFPA 45, Chapter 6-8.1.1, 6-11.2, 6-11.6

NFPA 99, 5-4.3.3

ANSI/AIHA Z9-5-1992, 5.12

Type 316 stainless steel (SS 316) is specified to avoid corrosion, thereby extending fume hood life. Splashes of liquid containing radioactive materials can be easily cleaned when hoods are constructed of non-porous materials such as stainless steel. Perchloric acid digestion over time may result in the condensation and consequential formation of perchlorate crystals which, in large quantities, pose an explosion hazard, especially if combined with organic chemical condensate.

5. Hood inserts are only permitted for radioactive iodination procedures specifically approved by the UH Radiation Safety Officer.
6. Laboratory hoods shall be provided with a means of containing minor spills.

NFPA 45, Chapter 6-9.1.3

ANSI/AIHA Z9.5, 5.2

The means of containing minor spills might consist of a 6.4-mm ($\frac{1}{4}$ in.) recess in the work surface, use of pans or trays, or creation of a recess by installing a curb across the front of the hood and sealing the joints between the work surface and the sides, back, and curb of the hood.

7. There must be a horizontal bottom airfoil inlet at the front of the hood.

ANIS/AIHA Z9.5, 5.2

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

8. Adjustable baffles with horizontal slots must be present in the fume hood interior at the back and top when using chemicals, solvents, etc. that are heavier than air.

ANSI/AIHA Z9.5, 5.2

Locating the slots in this manner will attain reasonably uniform face velocity under different conditions of hood use as related to heat sources, size, and configuration of equipment in the hood.

9. Before a new fume hood is put into operation, an adequate supply of makeup air must be provided to the lab.

Good Practice per UH EHLS

A fume hood exhausts a substantial amount of air. For this reason, additional make up air must be brought into the room to maintain a proper air balance.

10. Face Velocity:

Radioisotope Laboratory fume hoods shall provide a minimum average effective face velocity of 120 linear feet per minute (fpm), with a minimum of 80 fpm at any point.

11. Certification: Laboratory fume hoods, when installed in a new or renovated laboratory space, must pass an ASHRAE Test that is performed after installation within the laboratory space.
12. Where the required velocity can be obtained by partly closing the sash, the sash and/or jamb shall be marked to show the maximum opening at which the hood face velocity will meet the requirements. Fume hood sashes shall be set at a minimum of 14" working heights and designed for an 18" working height.

Good Practice per UH EHLS

13. An airflow indicator shall be provided and located so that it is visible from the front of the fume hood.

NFPA 45, Chapter 6-8.7.1

ANSI/AIHA Z9.5-1992, 5.8

Follow manufacturer's procedures for calibration of air flow indicator during installation. Follow manufacturer's schedule for periodic calibration and maintenance parameters thereafter. Performance criteria for various airflow indicators are as follows:

- Kim Wipes: Shows inward flow
- Magnahelic Gauges: Mark on gauge inches water read when average face velocity at 120 fpm
- FPM Readout: Average readout is 120 fpm
- Audio/Visual Alarms: Go into alarm mode if average face velocity drops to 80 fpm

14. Baffles shall be constructed so that they may not be adjusted to restrict the volume of air exhausted through the laboratory hood.

NFPA 45, Chapter 6-8,1-2

15. Fans should run continuously without local control from hood location and independently of any time clocks or switches.

NFPA 45

16. For new installations or modifications of existing installations, controls for laboratory hood services (e.g., gas, air, and water) should be located external to the hood and within easy reach.

NFPA 45, Chapter 6-8.5.1

17. Shutoff valves for services, including gas, air, vacuum, and electricity shall be outside of the hood enclosure in a location where they will be readily accessible in the event of fire in the hood. The location of such a shut-off shall be legibly lettered in a related location on the exterior of the hood.

NFPA 99, Chapter 5-4, 3.6
NFPA 45

18. Laboratory hoods shall not have an on/off switch located in the laboratory. Exhaust fans shall run continuously without direct local control from laboratories.

NFPA 45

19. Drying ovens shall not be placed under fume hoods.
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Good Practice per UH EHLS

20. High limit switches shall not be installed in duct work or fume hoods.

Good Practice per UH EHLS

K. **Fume Hood Power and Electrical**

1. Chemical fume hood exhaust fans shall be connected to an emergency power system in the event of a power failure.

Good Practice per UH EHLS

This backup power source will ensure that chemicals continue to be exhausted.

2. Emergency power circuits should be available for fan service so that fans will automatically restart upon restoration after a power outage.

Good Practice per UH EHLS

Continual fan service will ensure that hazardous materials are exhausted continually.

3. **Momentary or extended 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.**
4. Fume hood ventilating controls should be arranged so that shutting off the ventilation of one fume hood will not reduce the exhaust capacity or create an imbalance between exhaust and supply for any other hood connected to the same system.

NFPA 99, Chapter 5-4.3.4

5. **In installations where services and controls are within the hood, additional electrical disconnects of one fume hood will not reduce the exhaust capacity or create an imbalance between exhaust and supply for any other hood connected to the same system.**

NFPA 45, Chapter 6-8.4.1

Locating services, controls, and electrical fixtures external to the hood minimizes the potential hazards of corrosion and arcing.

6. Hood lighting shall be provided by UL-listed fixtures external to the hood or, if located within the hood interior, the fixtures shall meet the requirements of NFPA 70, (National Electrical Code).

NFPA 45, Chapter 3-6

7. Light fixtures should be of the fluorescent type and replaceable from outside the hood. Light fixtures must be displaced or covered by a transparent impact resistant vapor tight shield to prevent vapor contact.

Good Practice per UH EHLS

Fluorescent bulbs radiate less heat than conventional bulbs while maintaining a safe and illuminated work area inside the hood.

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

NFPA 45, Chapter 6-8.5.1
NFPA Chapter 5-4.3.6 (Health Care)

L. **Sashes**

1. Hoods shall have transparent movable sashes constructed of shatter-resistance, flame resistant material and capable of closing the entire front face.

ANSI/AIHA Z9.5-2003
Good Practice per UH EHLS

2. Vertical-rising sashes are preferred. If horizontal sashes are used, sash panels (horizontal sliding (and must be 12 to 14 inches in width.

Good Practices per UH EHLS

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.

ANSI/AIHA Z9.5-2003, 3.1.1.

M. **Ducting**

1. Hood exhausts should not be manifolded together:
-

- Exhaust ducts from each lab unit shall be separately ducted to a point outside the building, to a mechanical room, or to a shaft.
- Connection to common chemical fume hood exhaust duct system shall be permitted to occur within a building only in any of the following locations-
 - i. A protected mechanical room
 - ii. Fire rated shaft
 - iii. A point outside the building

NFPA 45

Replacement of duct with same size and same size fan will trigger an automatic ASHRAE test for a fume hood. However EHLS may request one on a case by case basis.

2. Horizontal ducts must slope at least 1 inch per 10 feet downward in direction of airflow to a suitable drain or sump.

ANSI/AIHA Z9.5-1992, 6.1

Liquid pools and residue buildup which can result from condensation may create a hazardous condition if allowed to collect.

3. Ducts exhausting air from fume hoods should be constructed entirely of non-combustible material. Gaskets should be resistant to degradation by the chemicals involved and fire resistant.

NFPA 45, Chapter 6-5.1

4. Automatic fire dampers shall not be used in laboratory hood exhaust systems. Fire detection and alarm systems shall not be interlocked to automatically shut down laboratory hood exhaust fans.

NFPA 45, Chapter 6-10

Fire dampers are not allowed in hood exhaust ducts. Normal or accidental closing of a damper may cause an explosion or impede the exhausting of toxic, flammable, or combustible materials in the event of a fire.

5. Ducts must be made of a compatible material that co-exists with the type of chemical being exhausted.
6. All exhaust ducts must be tested as medium pressure duct @ 3" lwc. and test to not allow for more than 1% loss per 100 feet of duct.

N. Exhaust

1. New exhaust fans should be oriented in an up-blast orientation.

Good Practice per UH EHLS

Any other type of fan orientation increases the fan workload and increases the risk of exhaust emission re-entrainment.

2. Hood exhaust stacks shall extend at least 7 feet above the roof. Discharge shall be directed vertically upward.

Good Practice per UH EHLS

If parapet walls are present, EHLS recommends that stacks extend at least 2 feet above the top of a parapet wall or at least 7 feet above the roof, whichever is greater.

NOTE: The UH Facilities Planning and Construction office must be contacted if any building feature such as exhaust stacks, extend above the roofline.

3. Hood exhausts shall be located on the roof as far away from air intakes as possible to preclude recirculation of laboratory hood emissions within a building. For toxic gas applications, the separation distance shall be at least 75 feet from any intake.

Good Practice per UH EHLS

As future gas necessities are difficult to predict, EHLS recommends at least 75 feet for all applications.

4. **Discharge from exhaust stacks must have a velocity of at least 3,000 fpm. Achieving this velocity should not be done by the installation of a cone type reducer. The duct may be reduced, but the duct beyond the reduction should be of sufficient length to allow the air movement to return to a linear pattern.**

ANSI Z.95-2003, 5.3.5

Good Practice per UH EHLS

Strobic type exhaust fans may be used to address exhaust velocity needs.

5. Rain caps that divert the exhaust toward the roof are prohibited.

6. 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

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

Industrial Ventilation Manual

9. Exhaust fans shall be located outside the building at the point of final discharge. Each fan shall be the last element of the system so that the ductwork through the building is under negative pressure.
10. Fans shall be installed so they are readily accessible for maintenance and inspection without entering the plenum. If exhaust fans are located inside a penthouse, PPE needs for maintenance workers shall be considered.

NFPA 45

O. **Wind Engineering**

1. Wind engineering evaluations should be conducted for all wind directions striking all walls of a building where fume hood exhaust is likely to have significant ground level impact, or is likely to affect air intake for the same nearby buildings.

Good Practice per UH EHLS

2. Emergency generator exhaust should be considered in the wind engineering study.

Good Practices per UH EHLS

P. Noise

1. System design must provide for control of exhaust system noise (combination of fan-generated noise and air-generated noise) in the laboratory. Systems must be designed to achieve an acceptable Sound Pressure Level (SPL) frequency spectrum (room criterion) as described in the 1991 *HVAC Applications Handbook*.

ANSI/AIHA Z9.5, 10
1991 HVAC Applications Handbook

Acceptable SPL may vary depending on the intended room use. A Noise Criteria (NC) curve of 55 is generally adequate for a standard laboratory.

Q. Specialty, Controlled Climate, and Cold Rooms

1. The issue of ventilation in cold rooms during periods of occupancy or for storage of hazardous materials must be addressed. EHLS should be consulted to review arrangements for providing fresh and exhaust air during periods of occupancy and for storage of hazardous materials or compressed gases.

Good Practice per UH EHLS

Cold Rooms used only for the storage of non-hazardous materials must have latches that can be operated from the inside to allow for escape.

2. Specialty rooms, designed for human occupancy must have latches that can be operated from the inside to allow for escape.

Good Practice per UH EHLS
NFPA 101 Life Safety Code

3. Latches and frames shall be designed to allow actuation under all design conditions, such as freezing. Magnetic latches are recommended.

Good Practice per UH EHLS

4. Doors of walk-in specialty rooms must have viewing windows and external light switches.

Good Practice per UH EHLS

R. Lab Hood Commissions

1. Proper operation of fume hoods must be demonstrated by the contractor installing the fume hood prior to project closeout. Containment performance test per ANSI/ASHRAE 110 is required by EHLS.

ANSI/AIHA Z9-5-2003.6.3.7

Section 1.2**EMERGENCY EYEWASH AND SAFETY SHOWER EQUIPMENT****TABLE OF CONTENTS**

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A. Regulations, Standards and References

Regulations:

ANSIZ 358

Standards and References:

American National Standards Institute (ANSI), Z358.1
Emergency Eyewash and Shower Equipment

National Fire Protection Association
Health Care Facilities, Handbook 99, Chapter 10-6, Emergency Shower

Texas Accessibility Standard (TAS)

B. Scope

This Guide presents the minimum performance requirements for eyewash and shower equipment for the emergency treatment of the eyes or body of a person exposed to injurious materials. It covers the following types of equipment emergency shows, eyewash equipment, and combination shower or eye/face wash.

1. 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, which can cause corrosion, severe irritation, or is toxic, by skin absorption. Drench hoses, sink faucets, or showers are not acceptable eyewash facilities.

NFPA 99 Chapter 10-6

2. An emergency shower shall be provided for all work areas where, during normal operations or foreseeable emergencies, area of the body may come into contact with a substance which is corrosive, severely irritating to the skin or is toxic by skin absorption.

NFPA 99 Chapter 10-6

A deluge shower shall be installed within all acid washing areas.

C. Applications

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),
- 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 are handled outside their original shipping cartons.
- Waste accumulation areas that could contain corrosive waste materials.
- All work areas where formaldehyde solutions in concentrations greater than or equal to 0.1% are handled, and
- Areas where operations involve the use of air or water reactive liquids or solids.

29 CFR 1910.151

D. General Location

Where to Install

1. Emergency eyewash facilities and deluge showers shall be unobstructed and accessible locations that require no more than 10 seconds or 55 feet travel distance away from the injured person to reach along an unobstructed pathway (i.e., no doors without panic bars or which don't swing open when pushed). If both eyewash and shower are needed, they shall be located so that both can be used at the same time by one person.

ANSI Z358.1, 4.6.1 and 5.4.4

2. Americans with Disabilities Act (ADA) Emergency Eyewash/Showers: Install an emergency eyewash/shower so that a disabled person can access it within 10 seconds or 55 feet travel distance. These emergency eyewash/showers must provide appropriate accessibility (e.g., activation of controls and height of eyecups) to individuals in wheelchairs.

Signage

3. Emergency eyewash and shower locations shall be identified with a highly visible sign. The areas around the eyewash or shower shall be well lit and highly visible.

ANSI Z358.1

4. Whenever possible, the floor immediately beneath the eyewash and emergency shower, and to a radius of between about 12-30 inches, shall be a distinctive pattern and color to facilitate promoting a clear path of access and clearly identify the location.

Good Practice per UH EHLS

Prohibitions around Equipment

5. No obstructions, protrusions, or sharp objects shall be located within 16 inches from the center of the spray pattern of the emergency shower facility.

ANSI Z358.1

6. Electrical apparatus, telephones, thermostats, or power outlets should not be located within 6 feet of either side of the emergency shower or emergency eyewash facility (i.e., a 6-foot clearance zone) or have electrical equipment GFCI protected.

Good Practice per UH EHLS
N.F.P.A. 101 Life Safety Code

Prevent potential electrical hazards posed when the water generated by the activated emergency eyewash/safety shower is in proximity to live electrical equipment.

E. Eyewash Requirements

Flushing Rates

1. **A means shall be provided to ensure that a controlled flow of flushing fluid is provided to both eyes simultaneously.**

ANSI Z358.1, 5.1.1

2. **Eyewash equipment shall be capable of delivering to the eyes not less than 0.4 gallons per minute of flushing fluid for 15 minutes.**

ANSI Z358

Flushing Temperature

1. Any eye wash or eye wash combinations must incorporate an adjustable tepid watering valve for hot and cold to maintain a 60-90 degree temperature range.

All independent eye wash units

ANSI Z358.1, 5.1.1

Eyewash Positioning

2. The eyewash unit shall be positioned with the water nozzles 33-45 inches from the floor and 6 inches minimum from the wall or nearest obstruction. The unit must be located at an operable sink.

ANSI Z358.1, 5.4.1

Equipment Activation

3. The valve shall be designed so that the flushing fluid remains on without requiring the use of the operator's hands. The valve shall be designed to remain activated until intentionally shut off.

ANSI Z358.1.5.2 (a)

ANSI Z358.1.5.1.5

Eyewash Equipment Protection

4. Nozzles shall be protected from airborne containments. The removal of the nozzle protection shall not require a separate motion by the operator when activating the unit.

ANSI Z358.1, 5.1.3

F. Deluge Shower Requirements

1. The emergency shower location must have a level surface beneath the shower head.

Good Practice per UH EHLS
NFPA 101 Life Safety Code

Having a level surface will prevent the users from tripping while trying to access and use the emergency shower.

- 2. Emergency showerheads shall be designed so that a flushing fluid column is provided that is not less than 82 inches and not more than 96 inches in height from the surface on which the user stands.**

ANSI Z358.1.4.1

- 3. The shower head should not be mounted flush or recessed within any constructed surfaces or partitions and the center of the spray pattern shall be located at least 16 inches from any obstruction.**

Good Practice per UH EHLS
ANSI Z358.1, 4.1

Recessing the showerhead may limit access and/or affect spray pattern.

- 4. The spray pattern shall have a minimum diameter of 20 inches at least 60 inches above the surface on which the user stands.**

ANSI Z358.1, 4.1

Flushing Rates

- 5. Emergency showerheads shall be capable of delivering a minimum 75.7 liters per minute (20 gpm) of flushing fluid.**

ANSI Z358.1, 4.1

- 6. The shower should be attached to a flushing fluid supply from a 1-inch minimum iron pipe size (IPS).**

Good Practice (based on ANSI manufacturer's test procedures)

Equipment Activation

- 7. The valve shall be designed so that the flushing fluid remains on without requiring the use of the operator's hands. The valve shall be designed to remain activated until intentionally shut off.**

ANSI Z358.1, 4.2

- 8. The manual actuator, triangle pull, shall be located not more than 69 inches above the surface on which the user stands. The manual actuator shall be free from obstruction for 18 to 24 inches in all directions. The actuator shall**

not be mounted flush or recessed within any constructed surfaces or partitions.

ANSI Z358.1, 4.3

Design for Maintenance/Use

- 9. The water supply to showers and/or shower/eyewash combination units should be controlled by a ball-type shutoff valve, which is visible and accessible to shower testing personnel in the event of leaking or failed shower head valves.**

Good Practice per UH EHLS

This design will make maintenance easier.

- 10. A water flow device must be attached to the shower that activates the fire alarm system using a Priority 2 when water is flowing.**
- 11. The water that is discharged through the shower or eyewash must be tepid. Any eye wash or eye wash combinations must incorporate an adjustable tepid watering valve for hot and cold to maintain a 60-90 degree Fahrenheit temperature range.**

G. Testing

- 1. The contractor installing the emergency eyewash or shower equipment prior to project closeout and facility occupation must demonstrate proper operation of the equipment. Tags to allow monthly testing records to be kept shall be affixed to the showers and eyewash fountains.**

Good Practice per UH EHLS

By testing the equipment, UH can be assured that it is working properly before the users begin their research.

H. Approved Equipment

- 1. All emergency showers and eyewash facilities shall meet the requirements of ANSI Z358.1 and shall be installed in accordance with ANSI Z358.1.**

Section 1.3**PRESSURE VESSEL COMPONENTS AND SYSTEMS
AND COMPRESSED GAS CYLINDERS****TABLE OF CONTENTS**

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1. Regulation, Standards and References

NFPA 45, Chapter 8
NFPA 99, Chapter 4
NFPA 704, Chapter 2
UH Lab Safety Policies and Procedures
NFPA 55

2. Scope

The Guide applies to all UH facilities including leased properties. It covers all unfired pressure vessels (i.e., storage tanks, compressed gas cylinders) that have been designed to operate at pressure above 15 psig., including the storage and use of compressed gas cylinders and cryogenic fluids.

Note that there are numerous regulations governing the proper use of compressed gas cylinders; use is not addressed by the Guide, as it is a work practice issue rather than design feature.

3. Storage of Compressed Gas Cylinders – General

Location/Design

1. Laboratory design shall include a storage area for cylinders of compressed gases where:

- They are protected from external heat sources such as flame impingement, intense radiation heat, electric arc, or high temperature streamlines.
- They are in a well-protected, well-ventilated, dry location at least 20 feet from highly combustible materials.

NFPA 55
NFPA 99, 4-3.1.2

2. Adequate space shall be made available for the segregation of gases by hazard class. Flammable gases shall not be stored with oxidizing agents. Separate storage for full or empty cylinders is required. Such enclosures shall serve no other purpose.

NFPA 55
NFPA 99, Section 4-1.2(a)2

3. Piping systems

- Systems for other compressed gases and for cryogenic materials shall comply with the manufacturer's design and specifications.
- Each point of use shall have an accessible manual shut-off valve.
- The manual shutoff valve at the point of use shall be located away from the potential hazards and be located within 1.8 m (6 ft) of the point of use.
- Where the cylinder valve is located within immediate reach, a separate point-of-use shutoff valve shall not be required.
- Line regulators that have their source away from the point of use shall have a manual shutoff valve.
- An emergency gas shutoff device in an accessible location at the exit shall be provided in addition to the manual point-of-use valve in each educational and instructional laboratory space that has a piped gas-dispensing valve.
- Each and every portion of a piping system shall have uninterruptible pressure relief.
- Any part of the system that can be isolated from the rest of the system shall have adequate pressure relief.
- Piping shall be designed for a pressure greater than the maximum system pressure that can be developed under abnormal conditions. The system must be designed to a minimum of 1-1/2 times working pressure.
- A pressure relief system shall be designed to provide a discharge rate sufficient to avoid further pressure increase and shall vent to a safe location.
- Permanent piping shall be identified at the supply point and at each discharge point with the name of the material being transported.
- Piping systems, including regulators, shall not be used for gases other than those for which they are designed and identified unless a thorough review of the design specifications, materials of construction, and service compatibility is made and other appropriate modifications have been made.
- The piping and piping system shall be certified by an objective, qualified third party or the authority having jurisdiction to test and will provide certification and ample documentation proving piping and system integrity.

NFPA 45

4. Design features which are prohibited:

- **Unventilated enclosures such as lockers, cold rooms, and cupboards.**

Oxygen cylinders shall not be stored near highly combustible materials especially oil or grease, or near any other substances likely to cause or accelerate fire.

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

NFPA 55

6. The heating of flammable gas storage areas/facilities shall only be heated with the buildings new or existing environmental or climate control such as air, steam, hot water, etc.

Good Practice per UH EHLS

Cylinder Restraint Systems**7. Laboratory design shall include restraints for the storage of cylinders greater than 26 inches tall. The restraint system shall include at least two (2) restraints made of non-combustible materials, which are located at one-third and two-thirds, the height of the cylinder.**

NFPA 45, 8.1.5
NFPA 99, 4-3.1.1.2.3

A restraint system of chains, metal straps, or storage racks provides a reliable method of securing gas cylinders. Chains or metal straps at the bottom and top one third of each cylinder provide protection against tipping and falling. [Work Practice Note: When compressed gas cylinders in service, they shall be adequately secured by chains, metal straps, or other approved materials, to prevent cylinders from falling or being knocked over.]

8. The purchase and installation of compressed gas cylinder securing systems must be subject to review of EHLS.

Good Practice per UH EHLS

EHLS can assist in identifying good quality securing systems.

9. Gas cylinder securing systems should be anchored to a permanent building member or fixture.

Good Practice per UH EHLS

Connection to a permanent building member or fixture is needed to prevent movement.

D. Storage of Compressed Gas Cylinders – Toxic and Highly Toxic Gases

Note: The following requirements apply to occupancies only.

- Laboratory design shall incorporate storage capabilities of compressed gas cylinders of toxic and highly toxic gases per the following table. The number of lecture bottle cylinders [approximately 5 cm x 33 cm (2 in. x 13 in.)] shall be limited to 6.**

Table 6-1

	Flammable or Oxidizing Gases		Liquefied Flammable Gases		Gases with Health Hazard Rating of 3 or 4
	Sprinklered Space	Non-sprinklered Space	Sprinklered Space	Non-sprinklered Space	Non-Sprinklered or Sprinklered Space
Max. no. of cylinders per 46.5m² (500 ft²) or less	6	3	3	2	3

NFPA 45, Table 8-1

Storage Systems

2. Laboratory design shall include one of the following storage systems for toxic and highly toxic compressed gas cylinders:

- **Ventilated gas cabinets/exhausted enclosures/laboratory fume hoods, or**
- **Separate ventilated gas storage rooms without other occupancy or use which have explosion control.**

Good Practice per UH EHLS

3. When gas cabinets or exhausted enclosures are provided, they shall:

- a) Be located in a room or area which has independent exhaust ventilation;**
- b) Operate at negative pressure in relation to the surrounding area;**
- c) Have self-closing limited access parts or non-combustible windows to provide access to equipment controls with an average face velocity of at least 200 fpm and with a minimum of 150 fpm at any part of the access port or window, and with window design criterion of 200 fpm at the cylinder neck when the average face velocity is >200 fpm.**
- d) Be connected to an exhaust system;**
- e) Have self-closing doors and be constructed of at least 0.097 inch (12 gauge) steel;**
- f) Be anchored;**
- g) Contain no more than three (3) cylinders per gas cabinet, except where cylinder contents are one (1) pound net or less, in which case gas cabinets may contain up to 20 cylinders;**
- h) Be fitted with sensors connected to alarms to notify in the event of a leak, or exhaust system failure.**

Good Practice per UH EHLS

4. When separate gas storage rooms are provided, they shall:

- a) Operate at a negative pressure in relation to the surrounding area;**

b) Direct the exhaust ventilation to an exhaust system.

Good Practice per UH EHLS

Treatment

- 5. Treatment systems for the exhaust of toxic and highly toxic gases must be reviewed and approved by EHLS.**

EHLS Policies & Procedures

EHLS reviews treatments systems to ensure they are compliant and consistent.

Emergency Power

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

Good Practice per UH EHLS

Detection System

- 7. A continuous gas detection system shall be provided for Class I and II toxic gases to detect the presence of gas at or below the permissible exposure limit in occupied areas and at or below $\frac{1}{2}$ the IDLH (or 0.05 LC50 if no established IDLH) in unoccupied areas. The detection system shall initiate a local alarm and transmit a signal to a fire alarm system activating an audible alarm notifying building occupants of a toxic gas release. Activation of the monitoring system shall automatically close the shut-off valve on toxic and highly gas supply lines to the system being monitored.**

Good Practice per UH EHLS

Guidance about the gases to be monitored, alarm set points, and where and how the alarms annunciate must be provided by the campus EHLS.

- 8. An approved supervised smoke detection system shall be provided in rooms or areas where highly toxic compressed gases are stored indoors. Heat detectors may replace smoke detectors.**

Security

- 9. Storage areas shall be secured unauthorized entry.**
- 10. Failsafe exhaust interlock – Should the system detect a loss of exhaust the detection system shall initiate a local alarm and transmit a signal to a fire alarm system activating an alarm.**

11. Signage is required for toxic cylinder rooms clearly marked “DO NOT ENTER”.

Good Practice per UH EHLS

E. Storage of Compressed Gas Cylinders – Medical Gases

- 1. Enclosures such as 1-hour interior and exterior rooms (detailed below) must be provided for supply systems cylinder storage or manifold locations for oxidizing agents such as oxygen and nitrous oxide. Such enclosures must be constructed of an assembly of building materials with a fire-resistive rating of at least one (1) hour and must not communicate directly with anesthetizing locations.**

NFPA 99, Sections 4-3.1.1.2(a).2

Other nonflammable (inert) medical gases may be stored in the enclosure. Flammable gases shall not be stored with oxidizing agents. Storage of full or empty cylinders is permitted. Such enclosures shall serve no other purpose.

- 2. A 1-hour exterior room shall be a room or enclosure separated from the rest of the building by not less than 1-hour-rate fire-resistive construction. Openings between the room or enclosure and interior spaces shall be smoke-and draft-control assemblies having no less than a 1-hour fire-protection rating. Rooms shall have at least one exterior wall provided with at least two vents. Each vent shall not be less than 36 square inches in area. One vent shall be within 6 inches of the floor and one shall be within 6 inches of the ceiling. Containers of medical gases shall be provided with at least one fire sprinkler to provide container cooling in case of fire.**

NFPA 99

- 3. When an exterior wall cannot be provided for the room, automatic sprinklers shall be installed within the room. The room shall be exhausted through a duct to the exterior. Makeup air to the room shall be taken from the exterior. Both separate air streams shall be enclosed in a 1-hour-rated shaft enclosure from the room to the exterior. Approved mechanical ventilation shall be in accordance with the International Mechanical Code and provided at a minimum rate of one (1) cubic foot per minute per square foot of the room area.**
- 4. Medical gas system cabinets shall be in accordance with the following:**
 - a. Operated at a negative pressure in relation to surrounding area,**
 - b. Provided with self-closing, limited-access ports or noncombustible windows to give access to equipment controls. The average velocity**

of ventilation at the face of access ports or windows shall not be less than 200 feet per minute with a minimum of 150 feet per minute at any point of the access port or window,

- c. **Connected to an exhaust system,**
- d. **Provided with a self-closing door,**
- e. **Constructed of not less than 0.097-inch (12 gauge) steel.**

F. 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 per UH EHLS

G. Design of Pressure Vessels and Systems

1. **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.

Section 1.4**FLAMMABLE LIQUID STORAGE CABINETS****TABLE OF CONTENTS**

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A. Regulations, Standards and References

NFPA 30 Chapter 4
NFPA 101 Life Safety Code
NFPA 45

B. Scope

Flammable liquid storage cabinets are intended for the storage of flammable and combustible liquids. This Guide applies to all UH facilities including leased properties. It covers the design, construction, and installation of Flammable Liquid Storage Cabinets. The Guide does not address the proper use of Flammable Liquid Storage Cabinets.

C. Design

Approval/Submittal

1. **Flammable Liquid Storage Cabinets must be UL listed and must meet all NFPA Codes.**

NFPA

UL listing and EHLS approval assures a minimum level of quality consistent with code requirements and good practice.

Cabinet Capacity

2. **Where flammable liquid storage cabinets are required, they shall be designed such that they do not exceed 60 gallons for the combined total quantity of all liquids (i.e., Classes 1, 2, and 3).**

NFPA 30, Chapter 4-3.1

One or more Flammable Liquid Storage Cabinets are required for laboratories which store, use, or handle more than 10 gallons of flammable or combustible liquids depending on location.

Labeling

3. **Flammable Liquid Storage Cabinets shall conspicuously be labeled in red letters on contrasting background “FLAMMABLE – KEEP FIRE AWAY.”**

NFPA 30, Chapter 4-3.5

-
- 4. When flammable or combustible liquids present multiple hazards, the laboratory design shall address the storage requirements for each hazard.**

NFPA 30, NFPA 45

For example, acetic acid is a corrosive and flammable material. Therefore, if stored in a flammable cabinet with other flammable materials, it must be segregated through the use of separate barriers (e.g., secondary containment). Incompatible material shall not be stored within the same cabinet.

D. Construction

Materials

- 1. New Flammable Liquid Storage Cabinets must be constructed of steel and UL approved.**

Good Practice per UH EHLS
Wood Cabinets are not UL listed or EHLS approved.

- 2. Flammable Liquid Storage Cabinets shall be constructed as follows:**

- 1. Minimum wall thickness of 0.044 inches (18 gauge).**
- 2. Double walled construction with a minimum air gap of 1-1/2 inches between the walls including the door, top, bottom, and sides.**
- 3. Tight-fitting joints welded or riveted.**
- 4. Liquid-tight bottom with a doorsill of at least 2 inches.**
- 5. Three-point latch on doors.**

NFPA 30, Section 4-4.4(b)
Good Practice per UH EHLS

Doors

- 3. Cabinet doors shall be self-closing and self-latching.**

Good Practice per UH EHLS

Venting

- 4. Flammable Liquid Storage Cabinets are not required to be vented, except for odor control of malodorous materials. Vent openings shall be sealed with the bungs supplied with the cabinet or with bungs specified by the manufacturer of the cabinet. If vented, cabinet should be vented from the bottom with make-up air supplied to the top. It should be vented to an approved location or through a flame arrester to a fume hood exhaust system. Construction of the venting duct should be equal to the rating of the cabinet.**

NFPA 30, Chapter 4-3.4
NFPA 99, Chapter 10-7,2.3

E. Location

- 1. Flammable Liquid Storage Cabinets shall NOT be located near exit doorways, stairways, or in a location that would impede egress.**

NFPA 101

- 2. Flammable Liquid Storage Cabinets must NOT be wall-mounted.**

Good Practice per UH EHLS
Wall-mounted cabinets are not UL Listed or Fire Marshal Approved.

- 3. Laboratory design must ensure that Flammable Liquid Storage Cabinets are NOT located near an open flame or other ignition source.**

Good Practice per UH EHLS

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.

F. Electrical Bonding

- a. All flammable storage cabinets are equipped with electrical bonding lugs to prevent static charge. All cabinets must be bonded with an NEC approved method.**

Section 1.5**HAZARDOUS MATERIALS STORAGE****TABLE OF CONTENTS**

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A. Regulations

NFPA 101 Life Safety Code
NFPA 1 Fire Code Handbook
NFPA 30

B. Scope

This design guide applies to the storage of hazardous materials. As noted in the introduction, the use of hazardous materials has direct bearing on the design of the laboratory, hence, the research operations should be well understood in the planning phases when designing the laboratory's hazardous materials storage.

C. Requirements

1. Laboratory design shall include spill control and secondary containment for the storage of hazardous materials liquids in accordance with the requirements of NFPA 30.

Notes:

- a) Design must allow for substances which, when mixed, react violently, or evolve toxic vapors or gases, or which in combination become hazardous by reason of toxicity, oxidizing power, flammability, explosiveness, or other properties, to be separated from each other in storage by distance or by partition, so as to preclude accidental contact between them.
- b) Explosion control shall be provided as required by NFPA 30 and NFPA 1 for storage of non-exempt quantities of the following materials.
 - Highly toxic flammable or toxic flammable gases when not stored in gas cabinets, exhausted enclosures or gas rooms.
 - Combustible dusts.
 - Class 4 oxidizers.
 - Unclassified detonable and Class 1 organic peroxides.
 - Pyrophoric gases.
 - Class 3 and 4 unstable (reactive) materials.
 - Class 2 and 3 water-reactive solids and liquids.

-
2. When the hazardous materials stored in a control area are not in excess of the amounts specified in the tables below, such storage shall conform to the Building Code requirements:

NFPA 30

3. When the hazardous materials stored in a control area exceed the amounts, such storage shall conform to the International Building Code requirements for Group H, Division 7 (“H-7”) Occupancy and all NFPA code requirements.

International Building Code

NFPA 45

D. Procedures

The following permitting and reporting procedures have design and project approval implications for any facilities project.

1. NFPA 45 Chemical Inventory Report Procedure as noted in this and other sections, the quantity of hazardous chemicals planned for use and storage within a project area has a direct impact on how the project is designed. This procedure should be implemented at the point that a form is submitted. The end result of the procedure is a summarized report showing the quantities of hazard classes planned for a project compared to limits shown in NFPA 45 Appendix 1 of this section. Contact the UH Fire Marshal for further information.

2. Texas Commission on Environmental Quality (TCEQ)

Laboratory ventilation and fume hoods and some other laboratory equipment are considered as permit by rule emission sources by the TCEQ.

3. Hazardous Waste Generator “registration” for “off-campus” facilities

Projects within the “campus site” are covered by the University’s existing Hazardous Waste Generator “registration”. Projects that are “off-site” must obtain a Hazardous Waste Generator “registration” before procedures that result in chemical wastes can be conducted. Contact UH EHLS for guidance and assistance.

4. Hazardous Material Storage shall comply with NFPA 45 per type of occupancy. See NFPA 45.10.1

Section 2**ADDITIONAL REQUIREMENTS FOR LABORATORIES USING RADIOACTIVE
MATERIALS, RADIATION PRODUCING MACHINES, OR LASERS****TABLE OF CONTENTS**

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A. Regulations, Standards and References

Regulations:

- Code of Federal Regulation (CFR) 10, Parts 20 and 35
- 25 Texas Administrative Code (TAC) 289
- UH EHLS Radiation Safety Manual (STIPULATED IN LICENSE)

University Policies:

- Policies of the UH Radiation Safety Committee

Recommendations:

- "Guide for the Preparation of Applications for Medical Programs" (RH 2010 4/90) (not formally adopted) (DOHS 2010)
- "Safe Handling of Radioactive Materials," National Council on Radiation Protection (NBS Handbook 92)
- "Safe Handling of Radionuclides," International Atomic Energy Agency (IAEA), Safety Series No. 1, (1973 ed. Is still current as of 1999)
- "Structural Shielding and Evaluation for Medical Use of X-rays and Gamma Rays of Energies up to 10 Me," National Council on Radiation Protection, Report No. 49
- "Radiation Protection Design Guidelines for 0.1-100MeV Particle Accelerators," National Council on Radiation Protection, Report No. 51, (NCRP51)
- Guide for the Preparation of Applications for Type A Licenses of Broad Scope, 2nd Proposed Revision 2 Regulatory Guide 10.5, Revision 2, USNRC (NRC10.5)
- "Recommendations for the Safe Use of LASERS," American National Standards Institute. (ANSI Z136.1)
- Radiation Protection in Educational Institutions NCRP 157

B. Scope

All radioactive materials used at UH are governed by the terms and conditions of the UH Radioactive Materials License issued by the Department of Health Services.

C. Decommissioning of Existing Facilities Prior to Demolition or Renovation

Decommissioning of existing facilities is an activity regulated by the State of Texas, contact Radiation Safety as early as possible (at least 120 days) before the planned initiation of construction. A plan for decommissioning must be drafted and submitted to the EHLS Radiation Safety, approved, and executed. A report of findings with corrective actions stipulated must be submitted to the UH EHLS and approved before demolition, renovation, or construction can begin.

D. Design Features for Radiological Labs

Approval Process

- 1. Proposals for new facilities must be submitted to the Radiation Safety Committee via Radiation Safety Officer for review. New facilities must require the approval of the Radiation Safety Committee prior to construction.**

UH EHLS Radiation Safety Manual

- 2. Shared facilities for the use of radioactive materials should not be included in plans for new buildings. If such facilities are deemed absolutely necessary, the facility must be under the direction, control and authority of a single principal investigator, who shall be accountable for maintaining the facility in a safe and orderly manner.**

UH EHLS Radiation Safety Manual

Architectural Considerations

- 3. Benches in laboratories must be capable of supporting weight of necessary shielding for gamma rays.**

NBS Handbook 92
IAEA Safe Handling of Radionuclides

- 4. When work involves gamma emitters (especially gamma irradiators) the floors and coatings must be able to support the gamma shielding.**

NBS Handbook 92
IAEA, Safe Handling of Radionuclides

- 5. When applicable, lead shielding must be incorporated in the structure. Based on the proposed type and quantities of radioactive materials, the Radiation Safety Program will determine the need for the shielding.**

Note that for the x-ray producing machines, shielding calculations will be performed by qualified personnel. Shielding design is to be in accordance with all applicable State Regulations and NCRP and ANSI standards. During construction the shielding must be inspected by the Radiation Safety while walls are open. After completion, the effectiveness of the installed shielding and protective design features shall be evaluated by the Radiation Safety Program.

National Council on Radiation Protection, Report No. 147

Security

- 6. Areas where radioactive materials or other radiation sources are used or stored shall be provided with adequate security (e.g., locks) to prevent removal or use by unauthorized personnel.**

UH EHLS Radiation Safety Manual

- 7. High radiation areas or very high radiation areas (as defined in 10 CFR 20.1602-2) shall be equipped with means to prevent inadvertent access and restrict access to only authorized personnel. Means to reduce exposure levels in the area may be required via an interlock device. In some applications, means to monitor the radiation levels in the areas shall be provided.**

10 CFR 20, 1601-2

- 8. High radiation areas or very high radiation areas (as defined in 10 CFR 20.1602-2) shall be equipped with a control device that energizes a conspicuous visible or audible signal so that an individual entering the area and the operator of the device are made aware of the entry.**

10 CFR 20, 1601-2

Waste Storage

- 9. Adequate space must be available for radioactive wastes generated by projects within the lab. Most radioisotope projects will need about 10 sq. ft. of floor space for containers and shields within a lockable area. Radioactive wastes must be properly segregated by half-life categories. Secondary containment and appropriate flooring with non-porous material is required.**

UH EHLS Radiation Safety Manual

E. Laser Radiation Items

- 1. Class IIIb and IV Laser facilities must be equipped with adequate shielding (e.g., thermal curtains using materials approved by the University's Fire Marshal, window glass that does not transmit direct laser radiation or the specular or diffuse reflections of the laser radiation (shutters or filters)). Portals and viewing windows must be designed to prevent any exposure above the permissible threshold limit value.**

ANSI Z136.1, 25 TAC 289.301

- 2. Class IIIb and Class IV laser facilities must be in rooms secured by locks. Class IV laser installations must be provided with interlocked warnings that indicate the status of the laser prior to entering the facility.**

ANSI Z136.1, 25 TAC 289.301

- 3. All Electrical outlets must be placed a minimum of 4 inches above the work surface unless a GFCI is installed. Flush mounting to the work surface is not acceptable.**

ANSI Z136.1

F. Ventilation Considerations

- 1. Ventilation requirements for the laboratories utilizing radioactive materials are dependent upon the types of materials used. Facilities that use radioactive gases shall be equipped with ventilation to adequately maintain concentrations to below allowable occupational exposure levels and to not permit escape of the gas to adjacent non-use areas such that concentrations exceed those allowed for uncontrolled areas. These range from no special requirements to those requiring separate exhaust systems equipped with “panic button” shut down switches. The Radiation Safety Committee will review the proposed uses and make specific recommendations appropriate for each facility.**

10 CFR 20: Appendix B
UH EHLS Radiation Safety Manual

- 2. Depending on the type and quantities of radioactive materials or the location of the facility, fume hoods used with volatile radioactive materials have specific design requirements. These are detailed in the Fume Hoods section of this Design Guide.**

G. Laser Ventilation Considerations

- 1. Appropriate ventilation to remove laser generated airborne contaminants must be provided for Class IIIb and IV lasers.**

ANSI Z136.1

- 2. Gas cabinets and adequate ventilation must be provided to mitigate the hazards associated with excimer laser gases or other lasers using toxic gases.**

3. All MRIs must meet applicable codes.

4. TESLA Magnets

Section 3
BIOSAFETY LEVEL 2 LABORATORIES
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A. Codes, Standards, and References

National Fire Protection Association (NFPA) Standard 45, Fire Protection for Laboratories

The Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH), ***Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets, 2nd Edition***

The Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH), ***Biosafety in Microbiological and Biomedical Laboratories, 5th Edition***

NIH Guidelines for Research Involving Recombinant DNA Molecules, March 2013

National Sanitation Foundation (NSF) International Standard 49

B. Scope

All of the biological research conducted at the University of Houston involves low to moderate risk etiological agents as defined by the (NIH), Section 1, of this Guide, General Requirements for UH laboratories, covers all design requirements for Biosafety Level 1 laboratory work areas. This section focuses primarily on the biosafety considerations for a Biosafety Level 2 laboratory.

C. Ventilation Considerations for Biosafety Level 2 Laboratories

1. **Air pressure in laboratories and animal care rooms should be negative in relation to the corridor or adjacent non-laboratory areas. Rooms housing immunocompromised animals should be at a positive pressure with respect to adjoining areas. Consult with EHLS for design details.**

CDC-NIH Biosafety in Microbiological and Biomedical Laboratories (ABSL 2, D.5)

Potentially harmful aerosols can escape from the containment of the laboratory room unless the room air pressure is negative to adjacent non-laboratory areas. As a general rule, air should flow from low hazard to high hazard areas.

2. **Dedicated sterile tissue culture rooms should be balanced neutral or slightly positive with respect to adjoining areas. Tissue culture rooms that involve the use of biohazardous agents shall be negative as stated in C-1 above.**

Good Practice per UH EHLS

This will minimize the potential for possible contamination of experiments within these rooms.

- 3. An autoclave shall be provided with a canopy hood, slotted exhaust, or other suitable means of local exhaust. In addition, autoclave rooms should have a minimum of 10 air changes per hour.**

Good Practice per UH EHLS

Unpleasant heat and odors will linger in the room unless provided with effective local exhaust and adequate frequency of air changes.

D. Biological Safety Cabinets and Other Containment Considerations

Approval/Type

- 1. All Biological Safety Cabinets (BSC) must be National Science Foundation (NSF) listed, UL approved, and installed in accordance with the manufacturer's requirements.**

Good Practice per UH EHLS

Cabinets, which when used and installed properly, will provide both product and personnel protection. However, if the cabinet is not installed properly (e.g., not ducting a Class II, B2 cabinet), then it will not be serviceable. Installation of a cabinet, which deviates from the listed NSF requirements, will void the NSF Standard 49 approved listing.

- 2. Biosafety Level 2 applications involving toxic chemicals or radionuclides, a Class II-B type cabinet must be installed.**

Good Practice per UH EHLS

Class II-B cabinets do not allow in-room venting of exhaust air and are thus appropriate for such uses. For Biosafety Level 2 applications, fume hoods are not appropriate; a fume hood is not designed for the usage of biological materials. An appropriate biosafety cabinet must be used. The exact type of BSC should be specified early in the design process.

Venting

- 3. The Biosafety cabinet shall be vented from the building if toxic or malodorous chemicals are used. A thimble connection to the exhaust is one way to exhaust a Class IIA cabinet.**

Fume hoods shall not vent into a BSC system. A dedicated duct or manifold system shall be used.

Primary containment for Biohazards, CDC/NIH
Good Practice per UH EHLS

4. Venting to external ducts shall be monitored.

Good Practice per UH EHLS

Where cabinets are connected to external ducts, a flow monitoring system with audible and visual annunciators shall be used to alert the cabinet users of loss of external ventilation. Alternatively, thimble connections or canopy mini-enclosures in cabinets shall be fitted with a ribbon streamer or equivalent attached at an edge through which air enters the device to indicate the airflow direction.

Location

5. Biological safety cabinets (BSCs) must be located away from doors and other high traffic areas.

NSF Standard 49, Annex E, I.A.1

Currents of air can disrupt and degrade the protective capability of the cabinet. All attempts should be made to neutralize any interference.

6. A biosafety cabinet should not be installed directly opposite of another biosafety cabinet or fume hood if spatial considerations allow otherwise.

NSF Standard 49, Appendix E

Laminar airflow is greatly hindered by the operation of a biosafety cabinet located directly opposite of another biosafety or autoclave. It is recommended to provide at least six feet between cabinets.

7. A biosafety cabinet should not be installed directly under air supply inlets.

NSF Standard 49, Appendix E

External air currents degrade the effectiveness of Biosafety cabinets. If possible, locate cabinets where air supply inlets will not interfere with performance.

8. A Biosafety cabinet should not be installed within 10 feet of an autoclave.

Good Practice per UH EHLS

Exhaust from an autoclave may contain heat and moisture that will blow into the face of the cabinet. This will cause air turbulence in the cabinet and adversely affect the performance of the unit. There is also an increase of potential contamination within the cabinet if the autoclave is not functioning properly since the steam may contain spores or aerosols.

9. **A 12-inch clearance should be provided behind and on each side of the cabinet to allow easy access for maintenance, and to ensure that the air return to the laboratory is not hindered. When the BSC is hard-ducted or connected by thimble unit to the ventilation system adequate space must be provided so as not to interfere with air flow.**
10. **Only non-ducted biosafety cabinets shall be considered for installation.**

Primary containment for Biohazards, CDC/NIH

These placement considerations are required to ensure maximum effectiveness of the primary barrier (BSC).

Natural Gas

11. **Open flames shall not be used in Biosafety Cabinets**

Good Practice per UH EHLS

UH EHLS has taken a strong stance against the use of gas burners or alcohol flames in Biosafety cabinets. The decision has been made in accordance with recommendations from numerous agencies. The Center for Disease Control and Prevention (CDC) reports that 'open-flames are not required in the near microbe-free environment of a biological safety cabinet' and create 'turbulence which disrupts the pattern of air supplied to the work surface' jeopardizing the sterility of the work area. This is also the recommendation of the World Health Organization (WHO) as well as the major Biosafety cabinet manufacturers.

Natural gas shutoffs shall be placed within arm's reach, a maximum of 24", from the from the lab egress door frame.

Autoclaves

12. **Design provisions should be implemented and EHLS shall be consulted in the event of potentially infectious spores, chemicals, or instruments need to be disinfected/sterilized.**

Natural gas lines must be painted yellow for ease of identification.

CDC-NIH Biosafety in Microbiological and Biomedical Laboratories (BSL 2, D.6)

Guidelines for Research Involving Recombinant DNA Molecules (NIH Guidelines) App. G-II-B-4-f

E. Biohazardous/Medical Waste

Biohazardous waste must be contained in appropriate secondary containers prior to disposal

Good Practice per UH EHLS

Biohazardous and medical waste must be placed in 'red bags' which are located within approved secondary containment. These waste receptacles are in addition to the non-hazardous waste bins used within the laboratory. Sufficient floor space must be planned in order to have enough room for the necessary waste containers.

F. Additional Considerations for Biosafety Research Laboratories

A. BSL 1

1. Laboratories should have doors for access control.
2. Laboratories must have a sink for hand washing.
3. The laboratory should be designed so that it can be easily cleaned. Carpets and rugs in laboratories are not appropriate.
4. Laboratory furniture must be capable of supporting anticipated loads and uses. Spaces between benches, cabinets, and equipment should be accessible for cleaning.
 - a. Bench tops must be impervious to water and resistant to heat, organic solvents, acids, alkalis, and other chemicals.
 - b. Chairs used in laboratory work must be covered with a non-porous material that can be easily cleaned and decontaminated with appropriate disinfectant.

B. BSL2

1. Laboratory doors should be self-closing and have locks in accordance with the institutional policies.
2. Laboratories must have a sink for hand washing. The sink may be manually, hands-free, or automatically operated. It should be located near the exit door.

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3. The laboratory should be designed so that it can be easily cleaned and decontaminated. Carpets and rugs in laboratories are not permitted.
 4. Laboratory furniture must be capable of supporting anticipated loads and uses. Spaces between benches, cabinets, and equipment should be accessible for cleaning.
 - a. Bench tops must be impervious to water and resistant to heat, organic solvents, acids, alkalis, and other chemicals.
 - b. Chairs used in laboratory work must be covered with a non-porous material that can be easily cleaned and decontaminated with appropriate disinfectant.
 6. BSCs must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. BSCs should be located away from doors, windows that can be opened, heavily traveled laboratory areas, and other possible airflow disruptions.
 7. Vacuum lines should be protected with liquid disinfectant traps.
 8. An eyewash station must be readily available.
 9. There are no specific requirements for ventilation systems. However, planning of new facilities should consider mechanical ventilation systems that provide an inward flow of air without recirculation to spaces outside of the laboratory.
 10. HEPA filtered exhaust air from a Class II BSC can be safely recirculation back into the laboratory environment if the cabinet is tested and certified at least annually and operated according to manufacturer's recommendations. BSCs can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or directly exhausted to the outside through a hard connection. Provisions to assure proper safety cabinet performance and air system operation must be verified.
 11. A method for decontaminating all laboratory wastes should be available in the facility (e.g., autoclave, chemical disinfection, incineration, or other validated decontamination method).

C. BSL 3

1. Laboratory doors must be self-closing and have locks in accordance with the institutional policies. The laboratory must be separated from areas that are open to unrestricted traffic flow within the building. Laboratory access is restricted. Access to the laboratory is through two self-closing doors. A clothing change room (anteroom) may be included in the passageway between the two self-closing doors.
2. Laboratories must have a sink for hand washing. The sink must be hands-free or automatically operated. It should be located near the exit door. If the laboratory is segregated into different laboratories, a sink must also be available for hand

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- washing in each zone. Additional sinks may be required as determined by the risk assessment.
3. The laboratory must be designed so that it can be easily cleaned and decontaminated. Carpets and rugs are not permitted. Seams, floors, walls, and ceiling surfaces should be sealed. Spaces around doors and ventilation openings should be capable of being sealed to facilitate space decontamination.
 - a. Floors must be slip resistant, impervious to liquids, and resistant to chemicals. Consideration should be given to the installation of seamless, sealed, resilient or poured floors, with integral cove bases.
 - b. Walls should be constructed to produce a sealed smooth finish that can be easily cleaned and decontaminated.
 - c. Ceilings should be constructed, sealed, and finished in the same general manner as walls.
 - d. Decontamination of the entire laboratory should be considered when there has been gross contamination of the space, significant changes in laboratory usage, for major renovations, or maintenance shut downs. Selection of the appropriate materials and methods used to decontaminate the laboratory must be based on the risk assessment.
 4. Laboratory furniture must be capable of supporting anticipated loads and uses. Spaces between benches, cabinets, and equipment must be accessible for cleaning.
 - a. Bench tops must be impervious to water and resistant to heat, organic solvents, acids, alkalis, and other chemicals.
 - b. Chairs used in laboratory work must be covered with a non-porous material that can be easily cleaned and decontaminated with appropriate disinfectant.
 6. BSCs must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. BSCs should be located away from doors, heavily traveled laboratory areas, and other possible airflow disruptions.
 7. Vacuum lines must be protected with HEPA filters, or their equivalent. Filters must be replaced as needed. Liquid disinfectant traps may be required.
 8. An eyewash station must be readily available in the laboratory.
 9. A ducted air ventilation system is required. This system must provide sustained directional airflow by drawing air into the laboratory from “clean” areas toward “potentially contaminated” areas. The laboratory shall be designed such that under failure conditions the airflow will not be reversed.
 - a. Laboratory personnel must be able to verify directional airflow. A visual monitoring device, which confirms directional airflow, must be provided at the
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laboratory entry. Audible alarms should be considered to notify personnel of air flow disruption.⁴⁴ Biosafety in Microbiological and Biomedical Laboratories

10. Photohelic type directional flow devices must be calibrated annually and be connected to an emergency power source.

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- b. The laboratory exhaust air must not re-circulate to any other area of the building.
 - c. The laboratory building exhaust air should be dispersed away from occupied areas and from building air intake locations or the exhaust air must be HEPA filtered.
 - D. Caisson systems shall be tested and certified annually.
 1. HEPA filter housings shall have gas-tight isolation dampers, decontamination ports, and/or bag-in/bag-out (with appropriate decontamination procedures) capability. The HEPA filter housing should allow for leak testing of each filter and assembly using a DOP challenge using a 99.99% standard. The filters and the housing should be certified at least annually.
10. HEPA filtered exhaust air from a Class II BSC can be safely re-circulated into the laboratory environment if the cabinet is tested and certified at least annually and operated according to manufacturer's recommendations. BSCs can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or directly exhausted to the outside through a hard connection. Provisions to assure proper safety cabinet performance and air system operation must be verified. BSCs should be certified at least annually to assure correct performance. Class III BSCs must be directly (hard) connected up through the second exhaust HEPA filter of the cabinet. Supply air must be provided in such a manner that prevents positive pressurization of the cabinet.
 11. A method for decontaminating all laboratory wastes should be available in the facility, preferably within the laboratory (e.g., autoclave, chemical disinfection, or other validated decontamination method).
 12. Equipment that may produce infectious aerosols must be contained in primary barrier devices that exhaust air through HEPA filtration or other equivalent technology before being discharged into the laboratory. These HEPA filters should be tested and/or replaced at least annually.
 13. Facility design consideration should be given to means of decontaminating large pieces of equipment before removal from the laboratory.
 14. Enhanced environmental and personal protection may be required by the agent summary statement, risk assessment, or applicable local, state, or federal regulations. These laboratory enhancements may include, for example, one or more of the following: an anteroom for clean storage of equipment and supplies with dress-in, shower-out capabilities; gas tight dampers to facilitate laboratory isolation; final HEPA filtration of the laboratory exhaust air; laboratory effluent decontamination; and advanced access control devices, such as biometrics.

15. The BSL-3 facility design, operational parameters, and procedures must be verified and documented prior to operation. Facilities must be re-verified and documented at least annually.

16. Fans should incorporate direct drive motors or close coupled (not belt driven).

GLOSSARY

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

Biosafety Level: Biosafety levels consist of laboratory practices and techniques, safety equipment, and a laboratory facility appropriate for the operations performed and 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*, 1988 and revisions, and recommend biosafety levels for particular pathogenic microorganisms.

Biosafety Cabinet (BSC)¹: 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 average 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 and discharged without recirculation.

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 filter (HEPA). This cabinet provides HEPA-filtered downward airflow within the workspace. Class II Cabinets are further classified as type A, type B1, type B2 and type B3.

Class II, type A (non-ducted), biosafety cabinets may have positive pressure contaminated internal ducts and may exhaust HEPA-filtered air back into the laboratory. Shall provide a minimum inward average face velocity of 75 feet per minute at the work opening.

Class II type B1 cabinets have all biologically contaminated internal ducts or plenums under negative pressure or surrounded by negative pressure ducts or plenums, exhaust HEPA filtered air through external ducts to space outside the laboratory, and have HEPA filtered down flow air composed largely of unrecirculated inflow air.

Class II type B2 cabinets (also known as “total exhaust” cabinets) have all biologically contaminated internal ducts or plenums under negative pressure or surrounded by negative pressure ducts or plenums, exhaust HEPA filtered air through external ducts to space outside the laboratory, and have HEPA filtered down flow air drawn from the laboratory or outside air.

Class II type B3 cabinets (also known as “convertible” cabinets) have all biologically contaminated internal ducts or plenums under negative pressure or surrounded by negative pressure ducts or plenums, exhaust HEPA filtered air

through external ducts to space outside the laboratory, and have HEPA filtered down flow air that is a portion of the mixed down flow and inflow air from a common exhaust plenum.

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 Pisa (760 mm Hg).

NFPA 1

Carcinogen: A substance is considered to be a carcinogen if:

- a) It has been evaluated by the International Agency for Research on Cancer (IARC) Monographs and found to be a carcinogen or potential carcinogen; or
- b) It is listed as a carcinogen or potential carcinogen in the Sixth Annual Report on Carcinogens published by the National Toxicology Program (NTP) or,
- c) It is regulated by Fed/OSHA or Cal/OSHA as a carcinogen

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).

- a) Class II Liquid. Any liquid that has a flash point at or above 100°F (37.8°C) and below 140°F (60°C).
- b) Class IIIA Liquid. Any liquid that has a flash point at or above 140°F (60°C) but below 200°F (93°C).
- c) Class IIIB Liquid. Any liquid that has a flash point at or above 200°F (93°C).

Compressed Gas:

- a) A gas or mixture of gases having a pressure exceeding 40 Pisa at 70°F in a container, or
- b) A gas or mixture of gases having a pressure exceeding 140 Pisa in a container at 130°F, regardless of the pressure at 70°F, or
- c) A liquid or mixture of liquids having a vapor pressure exceeding 40 Pisa at 100°F 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.

Control Area: A building or portion of a building within which the exempted amounts of hazardous materials are allowed to be stored, dispensed, used or handled.

Corrosive: A substance that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. For example, a substance is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described by the U.S. Department of Transportation in Appendix A to 49 CFR Part 173, it destroys or changes irreversibly the structure of the tissue in 4 hours. This term does not refer to action on inanimate surfaces.

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

Emergency shower: A unit that enables a user to have flushing fluid cascading over the entire body.

Explosive: A substance that causes a sudden almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.

Eyewash: A device used to irrigate and flush the eyes.

Flammable Anesthetic Gas: A compressed which is flammable and administered as an anesthetic including cyclopropane, dimethyl ether, ethyl chloride, ethyl ether and ethylene.

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

- a) **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 psig at 100°F (37.8°C).
1. Class IA liquids shall include those liquids that have flash points below 73°F (22.8°C) and boiling points below 100°F (37.8°C).
 2. Class IB liquids shall include those liquids that have flash points below 73°F (22.8°C) and boiling points at or above 100°F (37.8°C).
 3. Class IC liquids shall include those liquids that have flash points at or above 73°F (22.8°C), but below 100°F (37.8°C).

NFPA 1

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.

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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).

All fume hoods must be certified per ASRAI 110 protocol following installation within the lab, by an independent, third party certifying agency.

- Restricted Bypass Fume Hoods (Phoenix Valves) are designed for operation on a Variable Air Volume (VAV) exhaust system (not included with the fume hood). The bypass slots in these fume hoods have been designed to exhaust the minimum volume of air through the fume hood when the sash is closed. All hoods must meet NFPA 45 standards.
- Open Bypass Fume Hoods are designed for controlled airflow patterns within the fume hood for Constant Air Volume (CAV) exhaust conditions. The bypass slots are an alternate route for air to enter the hood as the fume hood sash is closed. These slots are sized to ensure that as the sash is closed, the fume hood face velocity does not increase to more than three and one half (3.5) times the velocity when the sash is fully open. The bottom airfoil guides air into the hood along the work surface. This feature allows a more uniform internal velocity to be maintained within the hood and provides a continuous air stream to sweep fumes from the countertop workspace. All fume hoods must meet NFPA 45 standards.
- Air Sentry (Low Flow Concept) Fume Hood. The future of Fume Hood Technology is here, now, with Air Sentry fume hood. The Air Sentry High Performance Fume Hoods can reduce the required airflow within the laboratory space by as much as half the amount that is normally required by conventional fume hoods. Even though this fume hood operates with reduced exhaust volumes and face velocities, the Air Sentry fume hood actually outperforms conventional fume hoods in containment tests. This high efficiency hood can be used on either CAV, VAV, or a switched two-state exhaust system. The Air Sentry Series fume hoods feature the Vortex Controls System, which automates the back baffle to adjust for external influences which may affect hood performance.

Hazardous Material: A material for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes materials which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes. The term "physical hazard" includes

materials for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, cryogenic, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive.

Hazard Warning: Any words, pictures, symbols, or combination thereof appearing on a label or other appropriate form of warning that convey the health and physical hazards of the substance(s) present.

Highly Toxic: A substance is considered to be highly toxic if:

- a) A substance that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.
- b) A substance that has a median lethal dose (LD50) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.
- c) A substance that has a median lethal dose (LD50) 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 weighing between 200 and 300 grams each.

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.

Irritant: A substance which is not corrosive, but which causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A substance is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 CFR 1500.41 for 24 hours exposure by other appropriate techniques, it results in an empirical score of 5 or more. A substance is an eye irritant if so determined under the procedure listed in 16 CFR 1500.42 or other appropriate techniques.

NIH: National Institute of Health

Nonflammable Medical Gas: A compressed gas, such as oxygen or nitrous oxide, which is nonflammable and used for therapeutic purposes.

Organic Peroxide: An organic compound that contains the bivalent –O-O- structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical.

Oxidizer: A substance other than a blasting agent or explosive that initiates or promotes combustion in other materials thereby causing fire either itself or through the release of oxygen or other gases.

Pyrophoric: A substance that will ignite spontaneously in air at a temperature of 130° (54.4°C) or below.

Risk Levels:

1. **LOW RISK:** risk level of agents and/or operations having minimal effect on personnel, other animal or plants under ordinary use. This classification is restricted to all etiologic agents designated as Biosafety Level 1 by the CDC.
2. **MODERATE RISK:** risk level of agents/or operations requiring special conditions for control or contaminated because of (a) known pathogenicity to personnel, other animals or plants; (b) concentration; or (c) genetic alteration (synergistic effect) with other materials. This classification includes all etiologic agents designated as Class 2 or 3 by the CDC (Biosafety Level 2 or 3) and oncogenic viruses specified as moderate risk by the National Cancer Institute (NCI).
3. **HIGH RISK:** risk level of agents and/or operations requiring additional control measures beyond those for moderate risk. This classification includes all etiologic agents designated Class 4 or 5 by the CDC and oncogenic viruses classified as high risk by the NCI.

Sensitizer: A substance that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the substance.

Toxic: A substance is considered to be toxic if:

- a) A substance that has a median lethal dose (LD50) of more than 50 milligrams per kilogram but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.
- b) A substance that has a median lethal dose (LD50) of more than 200 milligrams per kilogram but not more than 1000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.
- c) A substance that has a median lethal dose (LD50) in air of more than 200 parts per million but not more than 2000 parts per million by volume of gas or vapor, or more than 2 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 weighing between 200 and 300 grams each.

CCR, Title 24, Part 9, Section 221-T

Unstable (reactive): A substance which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions or shocks, pressure or temperature.

Vapor Pressure: The pressure, measured in Pisa, exerted by a liquid.

NFPA 1

Water-reactive: A substance that reacts with water to release a gas that is either flammable or presents a health hazard.