MIT
Design Standards

Lab Design

T10 Thematic Folder

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Department of Facilities

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MIT lab types include the following:

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1.2 Lab Design Standards

The general design and construction of laboratory fume hoods should conform to applicable guidelines in the current editions of:

- The American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation: A Manual of Recommended Practices, ANSI Z9.5 Laboratory Ventilation Standard and,
- The Scientific Equipment and Furniture Association (SEFA) Recommended Practices for Laboratory Fume Hoods.
- American National Standards Institute (ANSI)/ISEA Z358.1, Emergency Eyewash and Shower Equipment.
- Guide for the Care and Use of Laboratory Animals: Eighth Edition

2. LAB DESIGN: LAB TYPES

2.1 Baseline Laboratory

Planning

Laboratory means a facility where the "laboratory use of hazardous chemicals, biological or radioactive materials" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

*BSL2 laboratories are the most commonly found biological research laboratories at MIT, please refer to the BSL-2 section below for the requirements in ADDITION to the requirements listed in this section.

The following list outlines Requirements for all Laboratories:

1. Eating and drinking are not permitted in laboratories. Laboratory design should incorporate areas outside the labs to store food and a safe place to eat. When laboratories place write-up areas inside the laboratory zone, storage solutions for drink vessels should be provided for outside of the laboratory.
2. Mechanisms for controlling laboratory access must be in place. All laboratories must have doors for separation from public areas. The doors must be self-closing and lockable in order to control access to the laboratory and to research materials and information. Locking mechanisms on doors may include a standard keyed entry, a punch-code lock, a card reader, or a combination of these measures. Card readers may be preferred for laboratories of specific types/use.
3. Clearly identify and label the Building Occupancy Classification and Chemical Control Areas in the life safety documentation — Occupancy classification and control areas should be based upon an assessment of the projected chemical inventory of the building. Most teaching and research buildings should not require an H occupancy classification; however, individual H occupancy rooms may be necessary.
4. Each laboratory using hazardous materials, whether chemical, biological, or radioactive, should contain a sink for hand washing. Sinks for hand washing are required in each biological research lab as well as eye wash stations. The following considerations should be made when choosing a sink:

    a. Hands-free sinks (foot-pedal operated) are preferred since this reduces spread of contaminants from handles. Otherwise, consider use of paddle handles to minimize need to touch handles to turn water on and off.
    b. Sink screen strainers (fine mesh) should be considered to prevent sharps, i.e. needles, small pipette tips from going down the drain.
    c. Sink material should be compatible with chemical decontaminants commonly used in biological laboratories. They should be easy to clean and disinfect.

d. Note: Higher containment laboratories have specific sink requirements. Please see section 3.3.2 for more information.

5. There must be adequate in-laboratory storage cabinets to store reagents and chemicals and to provide segregation of incompatible materials. Storage design should be based on projected quantities and waste management practices. MIT has successfully utilized a ventilated sliding cabinet design adjacent to certain fume hoods as an option to achieve these goals.
6. All laboratories should have access to phone communication. An evaluation of the building and the hazards in the space will result in the recommendation of specific types of phones and locations. Consult with MIT EHS and MIT IST.

Planning Design Considerations

The following are planning issues to be discussed on a project-by-project basis:

1. Because the handling and storage of hazardous materials inherently carries a high risk of exposure and injury, segregate laboratory and non-laboratory activities to the extent possible. A possible example of this is to separate the offices and write up areas from the chemical usage areas. This separation can take the form of a glass wall that provides a direct line of sight into the laboratory, while still separating the HVAC, Plumbing, and finish requirements of the differing space types. Physical separation would allow the HVAC system to be tailored to each hazard area, with the 100% exhausted air system utilized in the higher hazard laboratories, while a more efficient recirculated system could be utilized in the office, conference, and collaboration areas. This strategy has the added benefit of reducing prohibited food and drink within the higher hazard laboratory zone.
2. If possible, a separation of corridors servicing laboratory operations and general public circulation through the building is desired to enhance the safety of all building inhabitants.
3. A typical new construction general laboratory requires a maximum vibration velocity of 50 µm/s and a structural criterion of 6,400 kips/in-sec. Certain specialty sciences may require more stringent criteria, please review specific vibration requirements with researchers.
4. If multiple laboratories will need nitrogen, carbon dioxide, or other specific gasses in large volumes, the project team should analyze merits of bulk tank(s) and distribution system.

Dimensions

Modular design is seen to be an advantage to the Institute, by rationalizing the “kit of parts” users and administrators utilize to fulfill their programmatic needs. Rational and repetitive sizing of laboratory bench components and shelving is encouraged. Here are some more specific dimensional goals:

1. A minimum door size of 36"- should be provided for the movement of people. At least one oversized opening of at least 42" clear should be provided into all laboratories to facilitate equipment movement. A 36" primary leaf with an 18" unequal secondary leaf would easily meet this requirement.
2. Laboratory benches, laboratory equipment and other furniture or obstacles shall be placed so that there is at least 5'-0" of clear egress throughout the laboratory. (see: Aisles - width below).
3. Laboratory doors that separate laboratory areas from non-laboratory areas are to be automatically self-closing.
4. Corridors outside the laboratory should be at least 6 feet wide to allow for movement of large equipment and allow for circulation of materials on carts, etc.; with internal laboratory "ghost" corridors a minimum of 5 feet clear.

Design laboratory workstations to accommodate the range of body dimensions that may be using the workstations. For example, computer and microscopes workstations may require height-adjustable work surfaces and chairs.

In specialized spaces with equipment such as roll-in Autoclaves & Glass Wash, special attention has to be spent coordinating any required slab depressions, and/or ramping required within the space.

Aisles

Aisles are to be a minimum of 5'-0" clear in width, and free from obstructions. The design team should allow for hazardous waste and trash receptacles within the bench design, allowing for the aisles to remain free of clutter and hazardous obstacles.

Finishes

Certain finishes are recommended for certain laboratory environments in order to maintain clean-ability and safety.

1. All work surfaces (e.g., bench tops, counters, etc.) should be impervious to the chemicals and materials used in the laboratory. Bench tops must be impervious to water and resistant to acids, alkalis, organic solvents and moderate heat.
2. The laboratories shall be designed so that they can be easily cleaned. This includes built-in components as well as furniture.
3. Laboratory furniture should be sturdy and easily cleanable, including upholstered materials. No fabric upholstery in labs using biological materials. Hard, non-porous surfaces, like plastic are preferred because they are more easily cleaned and decontaminated. Spaces between benches, cabinets, and desks should be easily accessible for cleaning.
4. Carpets, rugs, or non-cleanable window coverings are not appropriate in research laboratories.
5. In specialized spaces with equipment such as roll-in Autoclaves & Glass Wash, special

attention has to be spent selecting the correct abrasion/ anti-slip characteristics for the areas around equipment that become damp or wet as a consequence of normal operations.

Ductwork – see HVAC Division 23

Lab Waste Water.

All wastewater from laboratory sinks, floor drains, and other areas within MIT buildings that enters the public sanitary sewerage system MUST meet the MWRA limits on contaminants and pollutants within the waste water. Any new laboratory waste water site would require either a new permit, or be added to MIT's discharge permit.

Equipment such as cage washers that contribute solids to the discharge shall have a system designed for the removal of the solids.

Laboratory waste water is to be treated by the MIT EHS approved waste water treatment system. (An acid neutralization system being the most common). Chip Tank waste water treatment systems are NOT permitted at MIT.

See MIT Design Guidelines section on plumbing for specific information and alternatives for acceptable cooling water options. EHS prohibits the once-through or single-pass cooling techniques.

Questions about these policies should be directed to the Environmental Management Program (452-EHSS or (617) 452-3477).

References:

NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules, 2013.
CDC/NIH Biosafety in Microbiological and Biomedical Laboratories, latest edition

2.2 BSL-1 Laboratory

Planning

All BSL-1 Laboratory spaces should be designed to a BSL-2 standard. Please refer to "Section 2.3: BSL-2 Laboratory" below.

2.3 BSL-2 Laboratory

BSL2 laboratories are the most commonly found biological research laboratories at MIT. Design of biological research laboratories at MIT must comply with the NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines). Additional information about biosafety levels, biological agents and laboratory design elements may be found in the CDC/NIH Biosafety in Microbiological and Biomedical Laboratories (6th Edition).

1. Biological research laboratories must have net directional inward airflow (be under negative pressure) with air moving from public spaces into the laboratory towards the most contaminated or high-risk areas. This allows for control of exposures in case of a spill in the laboratory. Laboratory air may not be re-circulated to any other building spaces outside of the laboratory. Laboratory air must be exhausted to the outside. Please refer to section *3.2 Ventilation (section 16.2 EHS)* within this document.
2. Insect and Rodent control: Laboratories should be designed to prevent insect and/or rodent penetration, including sealing holes to prevent intrusion. If laboratory windows are operable, they must be fitted with fly screens.
3. Depending on the research and safety needs, laboratories may require the following equipment:

    a. Biological safety cabinets (Refer to Section 5. Biological Safety Cabinets for more details).
    b. Autoclaves (Refer to Section 7.4. Autoclaves for more details).

2.4 BSL-2 plus

Planning

Facility design, procedures and practices must fulfill all requirements of a BSL-2 laboratory with the addition of specific BSL-3 design components, practices and procedures, as outlined in *Biosafety in Microbiological and Biomedical Laboratories* and the *NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules*.

The following design guidelines are for common BSL-2+ laboratories. Occasionally, highly specific, customized requirements will be needed based on unique experimental needs. Unique laboratory designs may require Committee on the Assessment of Biohazards/Embryonic Stem Cell Research Oversight (CAB/ESCRO) review in addition to Biosafety Program (BSP) review.

- Laboratory Design

1. The laboratory plan must meet all requirements for BSL-2 laboratories as described in the previous section.
2. A door must physically separate the BSL-2+ laboratory from other research and public areas. In other words, the BSL-2+ laboratory must be a separate room. The entry door must be self-closing and the door should have a window so that personnel working at BSL-2+ can be seen (safety issue).
    a. For BSL-2+ laboratories designed for research with infectious agents that present an elevated risk, the addition of an anteroom may be prudent. BSP and CAB/ESCRO review will determine the need for this.
    b. BSL-2+ laboratories must not be accessible via unsecured public hallways. They should be designed such that they are only accessible through another laboratory of lower containment.

3. A hand washing sink and eyewash must be present in a BSL-2+ lab. The sink should be hands free (e.g., foot operated or infrared sensor), or have paddle faucet handles.
4. Consideration should be given to planning for placement of bio-waste boxes and freezers either in the anteroom or laboratory space. Bio-waste boxes may not be stored inside the BSL-2+ laboratory but may be stored in the anteroom.
5. Consideration should be given to storing CO2 tanks outside the BSL-2+ facility for easier replacement.

- Equipment

1. BSL-2+ laboratory equipment (including but not limited to automatic pipettes, micropipettes, microscopes, counting chambers, water baths, etc.) must be dedicated for use with BSL-2+ materials whenever possible. This necessitates the purchase of, and allocation of space for, redundant equipment for BSL-2+ use only.
2. A biological safety cabinet (BSC) or other physical containment device is required. BSCs are by policy to be vented to a canopy connection unless an exception is approved by the CAB/ESCRO.
3. There is no requirement for an autoclave within a BSL-2+ laboratory; however, one must be close by (e.g. same floor) for waste decontamination, unless other provisions are made for proper waste disposal. In the absence of an accessible autoclave, the installation of one nearby should be considered part of the scope of the project.

- Signage

1. It is preferred to have access to utilities serving a BSL 2+ lab outside the lab. Signage indicating the location of shutoff valves for gas, water, vacuum, and electricity serving the BSL-2+ facility should be posted on the entry door to the facility so that services may be shut down as needed without having to enter the research laboratory.

References:

NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules, 2013.
CDC/NIH Biosafety in Microbiological and Biomedical Laboratories, latest edition

2.5 BSL-3

All BSL-3 projects require ***very*** significant upgrades to the architectural and MEP systems over a BSL-2 plus laboratory standard. Any proposed BSL-3 project must be coordinated directly with MIT EHS, SEG, and Campus Construction for exact design requirements.

2.6 Engineering/Physical Sciences (Reserved)

2.7 Maker Spaces & Machine Shop

Refer to EHS Thematic Folder: Section 13

2.8 Chemistry

Planning

Organic and inorganic chemistry laboratory activities include mixing, heating, cooling, distilling, evaporating, diluting, and reacting chemicals for testing and research experiments. Many analytical procedures call for handling moderate amounts of hazardous chemicals, usually petroleum solvents, explosive gases, and all types of toxic substances. Usually this type of laboratory will be co-located within a building containing multiple laboratories. A Chemistry Laboratory must meet the criteria set out in Section 2.1 for a "Baseline" laboratory, along with these additional considerations.

Design Considerations:

1. It is extremely important to follow the fume hood placement guidelines outlined in the MIT placement criteria requirements, Section 5.9, in this document. The outlined clearances in this section are essential to maintain fume hood contaminant containment.
2. Allow for a high concentration of fume hoods, and utilize a Variable Volume ventilation system to vary supply and exhaust air based on use.
3. Install digital signs at the lab entrance displaying the laboratories exhaust airflow volume to inform and encourage users to close fume hood sashes for energy conservation.
4. Allow for deeper and taller fume hoods than standard, so as to accommodate a variety of required rig set ups within the hood.
5. Effluent gases from some analytical instrumentation (ex. gas chromatographs, absorption spectrometers, etc.) must be exhausted to the exterior of the building via non-recirculating (100% outside air) laboratory exhaust system. This may be a manifolded system within a fire control area. Effluent gases should be captured and exhausted from the laboratory via various methods such as canopy hoods, enclosures, duct drops, etc.. Note: Perchloric acid use requires dedicated hoods with the appropriate construction, materials, and internal wash-down capability. Please refer to Section 5.4. of this document for information on Perchloric fume hoods.
6. The heat load of each of the analytical instruments and auxiliary equipment should be evaluated when estimating heating and air conditioning requirements.
7. When high voltage equipment is installed in analytical chemistry laboratories, individual disconnects and emergency shut-off switches to equipment should be located beside and near equipment (within reach of all laboratory workers). Plan adequate space between equipment to allow for disconnect access, service, and cleaning.
8. The use of restricted chemicals in certain laboratories may require additional security measures beyond what is required for a typical laboratory. EHS can provide information on restricted chemicals.

2.9 Labs Utilizing Radioactive Materials and Radiation Producing Equipment

Introduction

This section describes requirements for labs that will use radioactive material(s) /radiation producing equipment. The goal in the design and construction of these facilities are to keep radiation doses As Low as Reasonably Achievable (ALARA). The MIT Radiation Protection Program shall be consulted for further information regarding the design of radiation facilities.

All laboratories utilizing radiation sources, both ionizing and non-ionizing, such as radioactive sources, radiation producing equipment such as analytical x-ray, lasers, superconducting magnets, etc, must meet all federal and/or local regulatory requirements for licensing/registration. These regulations and standards also can have facility design and construction requirements.

Consideration should be given to having all laboratory door access controlled by card proximity readers. The doors would remain locked at all times and access would be granted only to person associated with the lab space who have completed the required EHS training. Lab doors should have auto-closing mechanisms. Access control and security monitoring is required for high activity irradiator labs.

The following list is a summary of the radiation facilities that have specific requirements:

A. Facilities Containing Radioactive Material

B. Facilities Containing Radiation Producing Devices

C. Specifically Regulated Facilities

D. Facilities Containing Non-Ionizing Radiation

2.9.1 Radioactive Material Facilities (105 CMR 120.200 Standards for Protection against Radiation)

Radioactive materials (RAM) are materials composed of unstable radioactive atoms which spontaneously decay to reach a more stable state. During the decay process, they release excess energy in the form of radioactive particles (beta, alpha, neutrons) or electromagnetic waves/photons (gamma rays, X-rays). These radioactive materials are used as a tool in various research applications at the Institute. Some examples include radiotracers in biological studies and check sources for testing of radiation detection equipment used in defense applications.

2.9.1.1 RAM Facility Construction Design and Materials

For buildings where RAM use will be high, it is preferable to form a multi-user "hot lab" where the bulk of the radioactive material experiments will be performed and the stock radioactive material will be securely stored. This lab would be shared by many researchers for initial labeling experiments. Only lower activity samples would be taken to the individual labs for further experimentation. The floor in this "hot lab" should be rolled, seamless vinyl for ease of decontamination. Other security and construction requirement may be necessary depending on the details of the work and RAM being stored and used in this lab, contact MIT EHS RPP for specific facility requirements.

For a typical RAM lab, it is preferred to use materials that can be easily decontaminated in the construction of RAM facilities. Flooring material shall be non-porous and is recommended to be seamless. Many facilities have tile floors which are adequate; however, tiles may have to be removed in the event of a spill. Bench tops shall be non-porous and seamless where possible. Typical laboratory bench top materials are generally adequate.

Fume hoods with specialized ventilation are required when using volatile radioactive materials and powders. It is preferable that this hood be located in the multi-use “hot” lab and would be equipped with the appropriate filtration system (activated carbon or HEPA). Fume hoods shall be constructed of a surface that can be easily decontaminated such as stainless-steel. Ductwork is traditionally stainless steel, but PVC may be used under certain circumstances (consult MIT EHS RRP for details). Air sampling capabilities within the ductwork to assess potential releases of volatile radioactive material need to be considered. A sink for disposal of aqueous, biological, soluble liquid waste that meet regulatory requirements may be required for certain laboratories. These sinks should be able to be operated hands free (such as foot pedals) to prevent further contamination.

Radiation shielding may need to be incorporated into a facility’s design depending on the quantity and isotopes used. Some radiation fields, if unshielded, can affect radiation users and may extend into adjacent spaces affecting other facility occupants. For Gamma and/or X-ray emitting isotopes the use of dense materials, typically lead, for stock storage, local temporary shielding (e.g. lead bricks) and facility construction (e.g. leaded gypsum walls, leaded plexiglass windows, etc) may be necessary. If large quantities of these materials are required, the weight of the material should be considered. For shielding of neutron emitting isotopes MIT EHS RPP shall be consulted.

2.9.1.2 RAM Facility Physical Security

Access Control

All facilities that plan to use RAM must be equipped with adequate access control to prevent unauthorized access to the facilities. Laboratory doors should be equipped with an access control system to allow access to only authorized persons. Entrances to RAM facilities should be equipped with either:

- Proximity card reader
- Cypher lock punch code
- Lock and Key

Stock Storage (e.g. cabinets, drawers, refrigerators, freezers, etc) shall be equipped with a locking mechanism to prevent unauthorized access to radioactive materials. Examples are padlocks, combinations locks, and punch codes. Depending on the amounts of radioactivity and particular isotopes involved access control requirements can vary.

2.9.1.3 RAM Facility Equipment Requirements

Radioactive laboratories require a variety of laboratory safety equipment to minimize exposure to radiation as well as mitigate the potential for radioactive material contamination. Space should be allotted at the entrance of the laboratory for storage of Personal Protective Equipment (PPE) and radiation survey equipment so that it can be accessed prior to entering a potentially hazardous area. Additionally, a laboratory signage holder at the entrance of a RAM laboratory is preferred to allow for required regulatory warning postings and emergency response information.

Radioactive Waste Storage

When designing a RAM facility, adequate space must be provided for the waste containers so that they can be near the work being performed and accessible for frequent change-out when full. Either small bench top containers or large floor containers can be used depending on the amount of radioactive waste being generated. All radioactive waste is segregated by half-life (into three categories) and physical form (e.g., Solid, Liquid, Sharps, Mixed Hazardous Waste, Animal Carcasses, Liquid Scintillation Vials). Liquid waste containers need to be provided with secondary containment. Freezers for animal carcass storage may be required. Adequate storage space should be allocated for the variety of waste containers needed by an individual lab. For larger quantities of radioactive materials shielding should be considered. The following examples of shielding equipment should be discussed during the design as necessary:

- Beta Emitting Isotopes: The use of plexiglass for personnel shields as well as stock storage and waste containers.
- Gamma/X-ray Emitting Isotopes: The use of dense materials (typically lead) for stock storage, local temporary shielding (e.g., lead bricks) and facility construction (e.g., leaded gypsum walls, leaded plexiglass windows, etc).
- Neutron Emitting Isotopes: Consult MIT EHS RPP for neutron shielding requirements

2.9.2 Facilities Containing Radiation Producing Devices

2.9.2.1 Analytical X-Ray Labs

Standard laboratory design with a few additional considerations:

- Consideration for floor loading as these units can weigh thousands of pounds.
- Typically, higher voltage electric supply needed.
- Analytical x-ray machines with an open beam configuration, consideration must be given to either integral shielding within the facility walls, doors, and/or isolation barriers.
- Fully enclosed or cabinet type analytical x-ray equipment that does not emit any

increased radiation levels outside the enclosure requires only standard lab design.

- X-ray on warning light at lab entrance may be required.
- Room shall have access control system. Utilizing proximity card access is highly recommended.

2.9.2.2 X-Ray Irradiators

Standard laboratory design with additional considerations:

- Consideration for floor loading as these units can weigh between 6,000-9,000 pounds.
- Typically, a higher voltage electric supply is needed.
- Lab signage holder at entrance for required regulatory warning postings and emergency response information.
- Room shall have access control system. Utilizing proximity card access is highly recommended.

2.9.2.3 Fluoroscope-Diagnostic X-Ray Research Labs
Standard laboratory design with a few additional considerations. The MIT Radiation Protection Program shall be consulted during the design and review process.

- Typically, higher voltage electric supply is needed.
- Integral shielding in walls, ceiling, and doors must be considered depending on the x-ray machine use.
- A control booth for the operator with leaded walls/viewing glass may be necessary.
- An interlock and/or warning light shall be installed at all egresses. For diagnostic x-ray installations, the warning light shall be wired to the rotor of the x-ray system.
- Consideration of the projected use of adjacent rooms/spaces and their occupancy factors to assist in shielding design.
- If located in a vivarium, the room may have special ventilation requirements.
- Room shall have access control system. Utilizing proximity card access is highly recommended.
- See 105 CMR 120.400 “X-Rays in the Healing Arts” for additional requirements set forth by the Massachusetts Department of Public Health Radiation Control Program.
- See NCRP Report No: 49, “Structural Shielding Design and Evaluation for Medical Use of X-rays and Gamma Rays of Energies up to 10 MeV.”

Prior to construction a shielding plan shall be submitted to the EHS Radiation Control Program for review and approval.

2.9.2.4 Medical X-ray Facilities (105 CMR 120.400: X-Rays in the Healing Arts)

Background: X-rays are used as a diagnostic tool in medical and veterinary applications. Due to the fact that X-rays are very penetrating they pass though less dense tissues such as skin and are absorbed by more dense tissue such as bones and teeth. The X-rays that penetrate completely through the tissue are collected on a film on detection device this shows up as the white areas on an X-ray and the darker areas represent the dense tissue. Medical and dental x-ray facilities need to be designed in a way to protect the operator as well as other occupants of the facility.

Standard medical room design with additional considerations. The MIT Radiation Protection Program shall be consulted during the design and review process.

- Typically, higher voltage electric supply is needed.
- Integral shielding in walls, ceiling, and doors must be considered depending on the x-ray machine use.
- A control booth for the operator with leaded walls/viewing glass may be necessary.
- An interlock and/or warning light shall be installed at all egresses. For diagnostic x-ray installations, the warning light shall be wired to the rotor of the x-ray system.
- Consideration of the projected use of adjacent rooms/spaces and their occupancy factors to assist in shielding design.
- If located in a vivarium, the room may have special ventilation requirement.
- Room shall have access control system. Utilizing proximity card access is highly recommended.
- See 105 CMR 120.400 "X-Rays in the Healing Arts" for additional requirements set forth by the Massachusetts Department of Public Health Radiation Control Program.
- See NCRP Report No: 49, "Structural Shielding Design and Evaluation for Medical Use of X-rays and Gamma Rays of Energies up to 10 MeV."

Prior to construction a shielding plan shall be submitted to the Radiation Control Program for review and approval.

2.9.2.5 Dental X-ray Rooms (105 CMR 120.400 "X-Rays in the Healing Arts)

Background: X-rays are used as a diagnostic tool in medical and veterinary applications. Due to the fact that X-rays are very penetrating they pass though less dense tissues such as skin, and are absorbed by more dense tissue such as bones and teeth. The X-rays that penetrate completely through the tissue are collected on a film on detection device this shows up as the white areas on an X-ray and the darker areas represent the dense tissue. Medical and dental x-ray facilities need to be designed in a way to protect the operator as well as other occupants of the facility.

Standard dental room design with additional considerations. The MIT Radiation Protection Program shall be consulted during the design and review process.

- See 105 CMR 120.400 "X-Rays in the Healing Arts" for additional requirements set forth by the Massachusetts Department of Public Health Radiation Control Program.
- See NCRP Report No. 145: Radiation Protection in Dentistry of additional requirements.
- Prior to construction a shielding plan shall be submitted to the Radiation Control Program for review and approval.

2.9.2.6 Accelerator Facilities (105 CMR 120.700: Radiation Safety Requirements for Particle Accelerators)

Background: Accelerators are machines capable of accelerating charged particles (e.g., electrons, protons, deuterons, etc) in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 MeV. For purposes of this definition, "particle accelerator" is an equivalent term.

The MIT Radiation Protection Program shall be consulted during the design and review process.

Accelerator facilities range from simple to very complex systems. The requirements of 105CMR120.700 and 105CMR120.200 shall be met and the Radiation Protection Program must be contacted early in the planning phase to ensure shielding designs are appropriate for the facility.

Some general considerations are as follows:

- Typically, a higher voltage electric supply is needed.
- Integral shielding in walls, ceiling, and doors must be considered depending on the accelerator operating characteristics.
- The orientation of the accelerator should be chosen to minimize public doses.
- A remote, control booth for the operator may be necessary.
- Space should be allotted at the entrance of the facility for storage of Personal Protective Equipment (PPE), personal dosimeters (i.e. a “badge board”) and radiation survey equipment so that it can be accessed prior to entering a potentially hazardous area.
- An interlock system may be required.
- Consideration of the projected use of adjacent rooms/spaces and their occupancy factors to assist in shielding design.
- The room may have special ventilation requirements.
- Room shall have access control system and be equipped with self-closing doors which remain locked at all times. Utilizing proximity card access is highly recommended.
- See 105 CMR 120.700 “Radiation Safety Requirements for Particle Accelerators” for additional requirements set forth by the Massachusetts Department of Public Health Radiation Control Program.
- See NCRP Report No: 49, “Structural Shielding Design and Evaluation for Medical Use of X-rays and Gamma Rays of Energies up to 10 MeV.”
- Prior to construction a shielding plan shall be submitted to the EHS Radiation Control Program for review and approval.

In addition, the ANSI N43.1, Radiation Safety for the Design and Operation of Particle Accelerators should be consulted in the design phase. Contact MIT RPP with any questions regarding accelerator facilities.

2.9.2.7 Other Machine Produced Radiation Facilities

Other equipment that may produce ionizing radiation either as part of the design of the equipment or incidental to its operation will need to be reviewed with respect to possible radiation exposures, shielding, and engineering controls. The provisions of 105CMR120.200, 120.020, 120.600, and 120.700 may apply. Examples of other radiation producing equipment found on campus are gyrotrons, klystrons, and fusors.

2.9.3 Specifically Regulated Facilities

2.9.3.1 Positron Emission Tomography (PET) and Computed Tomography (CT) Facilities (105 CMR 120.500: Use of Radionuclides in the Healing Arts)

PET scans use radioactive tracers to collect in an area of interest in the body that have high levels of chemical activity which correspond to areas affected by disease. When a PET scan is performed these areas are show up as highlighted regions. The isotopes used typically have high specific activities (leading to high dose rates) and a relatively short half-life. All items listed under the RAM Facilities must be implemented in the design of PET/CT facilities. More stringent requirements may be necessary due to the high dose rates from the isotopes used in these procedures.

Shielding calculations will need to be performed for walls, ceiling, and possibly the floor. Lead is the most commonly used shielding material for these facilities.

The layout of the space will need to be reviewed by the RPP to ensure that radiation exposures comply with the ALARA principle. Certain areas need to be in place for holding of radioactive animals, storage of waste, and sample preparation.

Standard laboratory design with a few additional considerations:

- Chemical fume hoods should be stainless steel to allow for ease of decontamination. Specialized ventilation is required if work will involve volatile radioactive material (radio-iodination experiments). This hood would be equipped with the appropriate filtration system (activated carbon or HEPA).
- PET isotopes generally have short half-lives so consideration should be given to having adequate decay-in-storage space to house radioactive carcasses until they are no longer radioactive and can be disposed with other animal carcass waste.
- Facilities that require the use of PET-CT equipment (typically in the vivarium), consideration must be given to assess the necessary shielding required in the lab to minimize worker and adjacent room public exposures. Portable and fixed lead shielding may be necessary depending on the types and amounts of PET isotopes to be used. Integral wall-door shielding may also be necessary.

2.9.3.2 Irradiator Facilities (105 CMR 120.620: Licensing and Radiation Safety Requirements for Irradiators)

Irradiators are devices which contain a sealed gamma emitting radiation source to irradiate (deliver radiation dose) a material, object, or device. At the institute irradiators are often used for animal studies and for testing electronic components specifically for space applications.

If the facility/laboratory will require high activity gamma irradiators containing category 1 or category 2 radioactive sources (thousands of curies of activity), consideration must be given to physical security requirements.

Standard laboratory design with additional considerations for security system recommendations:

- Consideration for floor loading as these units can weigh between 6000-9,000 pounds.
- Typically, a higher voltage electric supply is required.
- The room should have floor to ceiling fully grouted masonry walls, not sheetrock.
- Room supply/exhaust air system ductwork should be less than 12 inches in diameter.
- Room must have access control system utilizing both proximity card access and biometric validation for unescorted use. The access control system will be alarmed to detect any unauthorized/forced entry or a door held open for a defined period of time.
- Room will be supplied with motion detectors.
- Room equipped with radiation dose rate level monitors directly connected to security to alarm the detection of abnormal radiation levels.
- Panic buttons connected to security.
- Cameras/video system to allow security to triage alarm conditions and report to emergency first responders the conditions within the room.
- Cameras/video in the corridors leading to the irradiator facility to monitor entrance/exit.
- A telephone within the room to allow for communication with security.
- A 24/7 facility security monitoring station (dispatch) to monitor alarms from the irradiator facility to enable appropriate emergency response depending on the alarm conditions.
- Secure transmission of security communications between the facility and the security monitoring station.
- Lab signage holder at entrance for required regulatory warning postings and emergency response information.

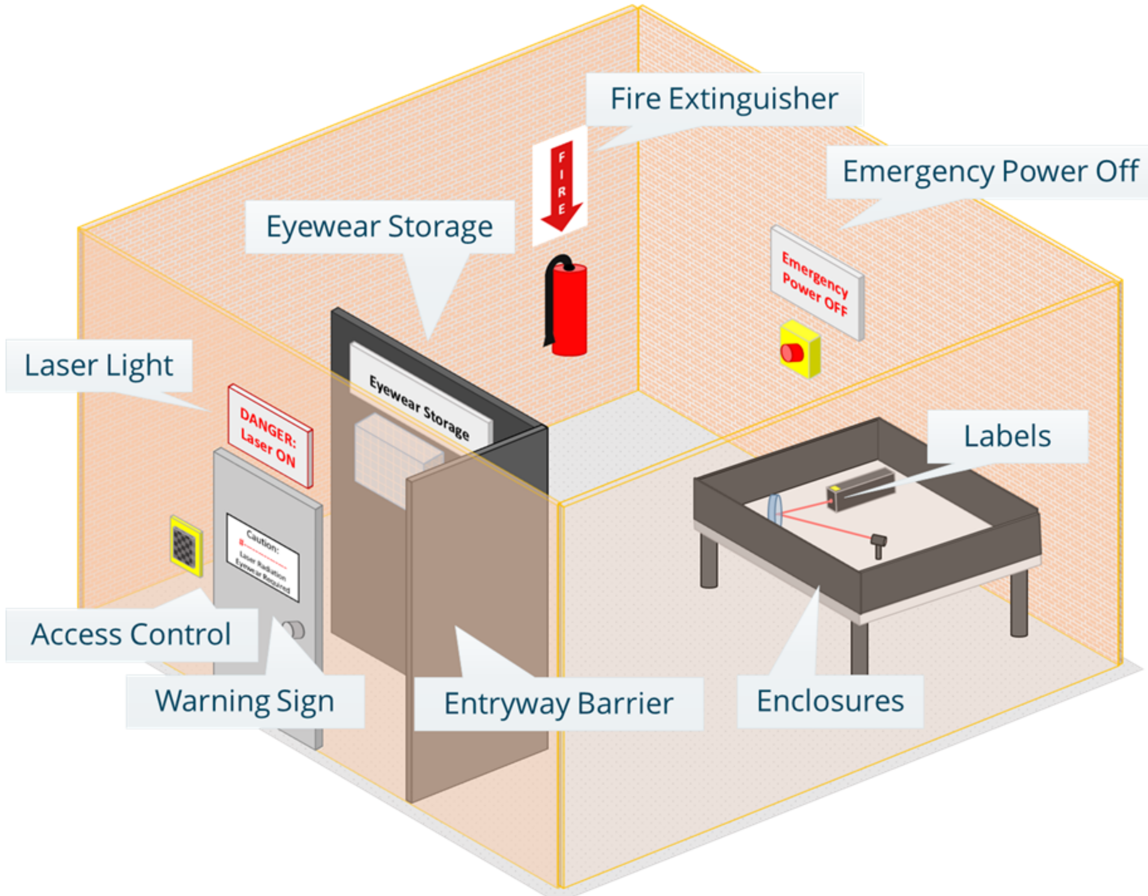
2.9.4 Facilities containing non-ionizing radiation

2.9.4.1 Laser Facilities (105 CMR 121.000: Laser Systems)

Laser radiation emitted from Class 3B and 4 lasers is considered to be potentially hazardous. Proper lab design can mitigate this hazard. This section is divided into two parts, covering both the exterior and interior design of a laser lab.

A visual overview of the safety requirements for a laser lab are provided in Figure 1 below.Figure **<u>1: Laser Lab Template</u>**

<u>Figure 1: Laser Lab Template</u>


Fire Extinguisher
Emergency Power Off
Eyewear Storage
Laser Light
Labels
Access Control
Warning Sign
Entryway Barrier
Enclosures
FIRE
Emergency Power Off
Eyewear Storage
DANGER: Laser ON

Section 1: Exterior Design:

This section provides requirements and recommendations for the exterior of laser labs.

Access Controls / Controlled Entry

Class 3B and 4 laser labs require access control. The most common controls are:

- Door interlock systems
- Electronic lock (keypad / RFID)

Door Requirements

- Doors must be self-closing
- Access control is required to exclude unauthorized personnel. Keypad/RFID electronic locks should be installed. Standard keyed locks are not recommended.
- Doors must be light tight, i.e. a strip at the bottom of the door similar to weather stripping and a protective strip covering the space between the doors (astragal) if a double door entrance is used.

Posting Requirements

- Illuminated warning sign
  - A flashing lighted laser sign shall be installed outside every access door to the laboratory.
  - The sign can be controlled by an interlock or a light switch, which shall be installed in a convenient position, easily accessed by laboratory personnel.
  - Consult with EHS Radiation Protection to source an appropriate light and to determine preferred control method
- Additional postings will be required, so space shall be left on the door for additional sign holders. EHS will provide postings and sign holders once the laboratory is operational.

Windows

A laser laboratory should be light-tight. Therefore, any windows that are installed must be covered with laser-rated material. Contact EHS Radiation Protection to determine the appropriate materials to use for this purpose.

Section 2: Interior Design

This section provides requirements and recommendations for the interior of laser labs.

Room Design

Room should be designed with adequate egress, consistent with life safety rules, surrounding the optical table.

Exposed pipes should be avoided where possible, or covered with a ceiling baffle for ceiling-mounted piping or matted/insulated for wall-mounted piping.

Entryway Area

The room shall be designed so that the laser beam can never escape into the hallway. This can be achieved by building an alcove in front of the door or by covering it with a laser safety barrier. This entryway area shall allow enough room for people entering to put on eye protection and shall not interfere with fire sprinklers. Barrier materials should meet requirements for fire safety. Consult with EHS Radiation Protection to determine appropriate entryway controls.

Laser Eyewear Storage

A critical element of laser safety is laser protective eyewear; hence, the storage and protection of that eyewear is very important. Laser eyewear should be stored in the entryway area. Storage shelf or rack must protect the physical integrity of the eyewear and be easily accessible to the users.

Laser Optical Table

- Consider weight of optical table.
- An overhead rack should be installed with power for equipment to be used on the optical table. Optionally, Overhead shelves or equipment racks can be installed as desired and task lighting can also be installed.
- Optical tables should be grounded.

Emergency power off (EPO*)*

A red mushroom type button or equivalent should be installed to cut power to at least one outlet in the room near where the laser will be used. This button should be easily accessible in an emergency. Consult EHS Radiation Protection to determine specific EPO requirements for a given laser system.

Laser Barriers

In addition to window coverings and entryway areas, laser barriers and curtains may be installed in additional locations as required by the project. Laser curtains should hang from rollers without blocking sprinkler systems and shall be made of material in accordance with local fire code and rated in accordance with ANSI Z136.1 for the laser power and wavelength. EHS Radiation Protection should be consulted during barrier selection.

Conduit

Wiring channels should be run for interlock controls and remote firing/monitoring if applicable. If lasers are to be transported via fiber optics, a separate conduit should be made with appropriate labeling.

Work Stations

If computer workstations will be located in the laser lab, consider locating them in a section of the lab separated from the laser work area by a laser barrier or curtain.

Fumes / Gas Cylinders/Toxic Gas alarms

- Laser facilities using toxic gases or burning/cutting must have the appropriate ventilation (such as toxic gas cabinets). If hazardous chemicals will be used a chemical fume hood must be available.
- If laser uses toxic gas (eg. excimer laser), a toxic gas alarm system must be present.

2.9.4.2 Magnet Laboratories/ Magnetic Resonance Imaging (MRI) Facilities: NMR, MRI, EPR and Other Strong Magnet Use Labs

If the facility will require the use of equipment that may generate large magnetic fields such as MRI/NMR/EPR, consideration must be given to assess the necessary magnetic field shielding requirements in the walls, ceilings, and doors. The MIT Radiation Protection Program shall be consulted during the design and review process. There are numerous and detailed considerations to be accounted for in the design of MRI's that need to be discussed and taken into consideration with the end user, MRI vendor, shielding vendor, EHS, and the design team.

Following are general considerations for strong magnet labs:

- Entryway postings are required if a significant hazard is possible. Hazards may include but are not limited to strong attractive forces, cryogens, and pacemaker or other medically implanted device interference.
- Demarcation of fringe fields must be considered if the field may extend into accessible areas and pose a potential hazard. Areas with magnetic fields higher than 5 gauss should be marked.
- Demarcation of fields and warning postings in adjacent areas must be considered if the magnetic field could extend into adjacent occupied spaces.
- Incorporation of integrated shielding in walls, ceilings and doors should be considered for large magnetic fields.
- Ventilation for quenching and incorporation into the TGMS should be considered where cryogens are used.
- Protection or storage for credit cards, watches, cell phones, etc. where strong magnets could cause projectile hazards or damage.

Limits for personnel exposure can be found in the American Conference of Governmental Industrial Hygienists (ACGIH) "Threshold Limiting Values (TLV) guidance on Static Magnetic Fields" and/or the International Commission on Nonionizing Radiation (ICNIRP) "Guidelines on Limits of Exposure to Static Magnetic Fields". In addition, magnetic resonance imaging systems for human subjects should follow the American College of Radiology Guidance for Safe MR Practices.

2.9.4.3 Radiofrequency Laboratories

Systems that emit radiofrequency (RF) energy as an intentional emitter need to be reviewed by MIT EHS if system power is in excess of 5W Effective Isotropic Rated Power (EIRP) to ensure that exposure levels meet the requirements of the MDPH 105CMR122.000 and those of the IEEE C95.1. Unintentional emitters shall be shielded to preclude exposures in excess of the limits in the regulations and standards as noted above. All systems shall be designed to operate in a non-interference mode in accordance with 47CFR15 which may require the use of RF shielding.

2.11 Imaging Laboratories

Ideal Vibration Criteria for Floor Structure

Limit center bay vibration velocity to 2,000 microinches/second due to building resonances and footfall induced vibration including slow walking speed within labs and moderate walking speeds in adjacent corridors. Regions within 5 feet of columns shall be restricted to a vibration velocity of 600 microinches / second with inducer located at center of bay. This will provide a laboratory environment where approximately 45% of the lab are 500 and 1,000 micro-inches/second; approximately 10% are between 1,000 and 1,500 micro-inches/second; and only 20% are between 1,500 and 2,000 micro-inches/second. For vibrations induced by mechanical equipment, structural slabs between lab and mechanical spaces shall be constructed to a minimum mass of 350 Kg/M2 in order to provide an appropriate base for equipment isolators to work against. The design approach will then be to provide equipment isolation to preclude vibrations from being transferred into the structure.

Vibration Dampening Tables

Tables may be designed for up to 4000 lbs. gross load capacity. Therefore, PM needs to have an expert evaluate if the floors may need reinforcement to handle this equipment depending on the table and application. Most vibration damping tables require compressed gas. Therefore, secure cylinder storage or house supplied air must be available. Granite tables offer some damping but are typically no longer used.

If the table will be used for in vitro electrophysiology, an electrical ground connection and vacuum supply should be available. Additional room shielding may be recommended. Typically, a Faraday cage will be placed on the anti-vibration table. Surgical platforms for in vivo electrophysiology may also require vibration damping tables. For both in vivo and in vitro setups, here should be enough room for the table as well as equipment racks. The room should be segregated to minimize interference from other research activities.

Several disciplines, particularly those associated with biological research, may require vibration damping for microscopy. Vibration damping tables may be required for surgical stations, confocal imaging technology, scanning electron microscopy, scanning probe microscopy and conventional optical microscopy.

2.12 Clinical Laboratory

Planning
The layout of a clinical laboratory will be determined by its size and by the nature and number of clinical tests that will be performed as well as by the number of staff, number of shifts, and number of automated instruments. Clinical laboratories resemble a combination of analytical chemistry and biological laboratory. Special requirements may be imposed by the Joint Commission on Accreditation of Health Care Organizations (JCAHO, 2001). In addition, special process workstations, laboratory benches, and seating should be carefully designed to aid the ergonomic safeguards of workers, because clinical laboratory activities are highly repetitive and many have the potential to cause repetitive stress injuries. A Clinical Laboratory must meet the criteria set out in Section 2.1 for a “Baseline” laboratory, along with these additional considerations.

Design Considerations

1. The clinical laboratory must meet the same criteria as the BSL-2 laboratory, with similar emergency shower, eyewash, autoclave, biowaste container storage areas ,BSC, and flammable storage requirements.
2. Due to the evolving trends in Clinical Laboratory design, the following zone flexibility is recommended:
    a. Least flexible: offices, bathrooms, lockers, etc.
    b. Semi flexible: blood bank, outpatient area.
    c. Highly flexible: all testing areas.
3. Storage facilities and refrigeration for reagents, standards, supplies, and stained glass specimen microscope slides shall conform to applicable NFPA standards.
4. A specimen collection facility may be located outside the laboratory suite, and will require the following:
    a. The blood collection area should have counter space, patient seating, and hand wash facilities.
    b. Specimen collection room should be equipped with water closet and lavatory.
5. If radioactive materials are employed, facilities must be available for long-term storage and disposal while meeting all applicable MIT EHS, City, State, and Federal regulations and guidelines.
6. Potential requirements:
    a. Glove box/ BSC (Biological Safety Cabinets).
        - Most Class II biological safety cabinets used in clinical laboratories will be Type A models that permit recirculation of air inside the laboratory.
        - When volatile chemotherapy drugs will be associated with clinical specimens, it is advisable to use a Type B cabinet that is exhausted to the outdoors through a direct connection to the roof.
    b. Local HVAC exhaust drops.
        - Canopy hoods.
        - Slot type capture hoods.
        - Flexible exhaust hose drops directly attached to equipment exhaust ports.
    c. Lab gas, compressed air, and vacuum drops.
    d. Significant IT requirements (sharp upward trend)
    e. Automated sample transportation systems (pneumatic tube or other)

2.13 Animal/ Survival Surgery (Reserved)

2.14 ABSL-2 (Reserved)

2.15 ABSL-2+ (Reserved)

3. LAB DESIGN REQUIREMENTS

3.1 Compressed Gases

Location Criteria

All laboratory construction shall include one or more of these strategies for the storage and use of Compressed Gas.

Cylinder brackets for gas cylinders, and alcoves for cylinders and cryogenic dewars shall not remain or be installed in exit or public corridors. Any existing cylinder brackets in exit or public corridor(s) must be removed.

Gases should not be used in spaces such as cold rooms, warm rooms, and other areas which may not have adequate fresh air ventilation. If gases must be used in such areas, Architect/Engineering team will contact the MIT CC Project Manager to engage MIT EHS for assistance in determining if oxygen monitoring or other gas monitoring is required and/or for help in selecting a monitoring system with local alarms.

Toxic, highly toxic, and, pyrophoric gases are required to be stored in gas rooms or approved cabinets, exhausted gas cabinets or exhausted enclosures in accordance with the requirements specified in 527 CMR, Chapter 60, Table 60.4.2.1.1.3.

It is recommended that the cylinders be stored in a ventilated area secured from unauthorized access). This can be a lab that has key or card access.

Care should be given to calculate the total volume of flammable gas to be used and stored in a given laboratory and/or control area in order to ensure compliance with the building code.

Cylinders should be located away from boilers, radiators, heaters and other heat producing equipment. Storage area temperatures should not exceed 125 °F, or below 0 °F. (Compressed Gas Association).

Strategies for the Location and Set-up of Compressed Gases

1. The following options should only be accessible via a secure non-public circulation/ corridor or laboratory suite:
   a. Build/install a specialized lab gas distribution manifold that can progressively switch (automatically or manually) supply between cylinders or dewars to meet demand, and are hard piped to distribution turrets or equipment throughout the laboratory. These manifolds can usually range from a 3 to 18 tank manifold, with the tanks being staked single or double file. Dependent on the orientation, the tanks can be safely secured via straps, chain, or steel tube frame tank restraints. Such manifolds can be housed in rooms or closets that are centrally located within the service zone outside of the laboratory, to allow for the least

disruptive delivery and replacement process possible. Include fire rated doors where required, and fire sprinklers, gas monitoring, and lab exhaust ventilation in the design of the room/closet. This space must be negatively pressurized to the adjacent corridor. Based on the hazards of the gases in this room/closet, determine if this area should not be used for anything else or if other lab equipment can be installed. Depending on gas cylinder/dewar type, distribution manifolds could also be located within open alcoves with the approved gases piped into the lab from that location. This strategy can be applied building wide.

   b. If a multi-tank specialty gas tank manifold cannot be located outside of the laboratory zone, then alternate locations can include adjacent support spaces, or low hazard areas of the lab where service and delivery of the manifold will not interfere with the operation of the laboratory, such as near the entrance (preferred).

2. If a (non-public, non-exit) service corridor is a minimum of 9'-0" wide, it can be reconfigured to create a service "linear equipment" room, with end-walls defining "equipment zones". All Linear Equipment rooms must still meet all building code requirements.
3. The review of possible exterior bulk storage of liquid nitrogen, carbon dioxide, etc. should be an overall design consideration for projects where large volumes are intended to be used.
4. In laboratories using Hydrogen gas, where there are large flammable gas volumes, or the location is on an upper floor, use of hydrogen generators can keep volumes within control area limits.
5. If direct source (no manifold) gas cylinders need to be set up in the lab next to equipment, fume hood, etc. to serve specific scientific needs, then dedicate wall space for an adequate number of restraints. Include extra restraints for back up cylinders and additional gases when the research changes. These restraints must be secured to a wall or other surface capable of restraining the weight of the cylinder(s). If stacked cylinders are required, a self-supporting tube steel frame (with built-in restraints) is recommended. Wherever feasible, compressed gas cylinders should be restrained singly, by use of a separate restraint system which will position cylinder valves so that they are accessible at all times. Do not install long chains that can be used for many cylinders and replace existing set ups during renovations. Cylinder brackets should be installed between 32"-36" a.f.f. (above finished floor) if the lab utilizes full size cylinders that ranging between 49"-55" in height. If smaller cylinders are being utilized within the laboratory, then any support brackets must be installed at the appropriate height for those cylinders. This is to ensure that cylinders will be safely secured at 2/3 the height of the cylinder. Installing brackets too high (near the valve) or too low (below the center of gravity) is not allowed.
6. If cylinders are stored outdoors, the project team must take care to not store cylinders directly on the ground. The storage area must be well drained, protected from the elements (including direct sunlight and vehicular traffic), and constructed of fire resistive material. Cylinder cages must be designed for outdoor storage.

Engineering Controls and Design for Gas Use

1. Include a suitable pressure relief device to protect a system using a compressed gas if the system has a pressure rating less than the compressed gas supply source and if, due to the gas capacity of the supply source or for any other reason, the system pressure rating may be exceeded.
2. Cylinders containing gases that pose health hazards and pyrophoric gases shall be housed in mechanically ventilated gas cylinder cabinets or fume hoods; Highly toxic, toxic and pyrophoric gases must be stored in ventilated, gas cylinder cabinets with a sprinkler head connected to the building sprinkler system. Check FM Global requirements for pyrophoric gases.
3. Include Gas Monitors /Interlocks / Alarms: Cylinder cabinets, fume hoods or other locally ventilated enclosures are required to be equipped with a continuous gas monitoring system with gas and ventilation alarm when used to store gases with NFPA health hazard rating =4 or =3, or when used to store gases that do not possess adequate warning properties or flammability rating =4. The alarm should warn of the presence of gases at or below the ACGIH TLV. See Gas or Vapor Monitoring section. Consideration should be given to providing monitoring, alarms and automatic shut off of gas flow upon other events besides gas detection, such as loss of power, high process pressure, loss of vacuum or loss of cooling.
4. Gas Cabinets shall be ventilated according to manufacturer's recommendations. The cabinet window should be labeled "Hazardous – Keep Fire Away".
5. Review need for scrubbing / treating of process and purge effluent from highly toxic gases prior to exhausting to the outside or capture catastrophic release of cylinder contents with the MIT EHS office.
6. Certain hydride gases can only be purchased with restricted flow orifices (RFOs). Review need for RFOs for these and other hazardous gases with MIT EHS office.
7. Flammable gas cylinders must be stored and used in well-ventilated areas. The MIT EHS Office must be consulted to determine whether ventilation in a given area is sufficient to allow storage and/or use of flammable gases.
8. Piping materials must be appropriate for the gases and pressures. Considerations for piping materials include:
    a. Inert gases - Reserved
    b. Toxic gases - Reserved
    c. Acetylene gas:
        - Steel piping can be used. Unalloyed copper tubing, valves or fittings shall not used, as it reacts with these materials.
        - A pressure regulator is used at the discharge of an individual cylinder
        - Rooms designed for storage of acetylene shall meet the requirements of NFPA 51, Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting and Allied Processes (NFPA 51)
    d. Anhydrous Ammonia gas:
        i. All piping, tubing, and fittings shall be made of material suitable for anhydrous ammonia service. Galvanized materials, cast iron, brass or copper pipe, or soldered joints for ammonia distribution piping should

not be used. Use extra heavy steel pipe where the pressure exceeds 125psi.

9. Bulk Oxygen systems:
    a. Oxygen cylinders, manifolds and emergency shut off valves should be located outdoors, if possible, or in detached buildings. If oxygen must be kept indoors, it should be located in a cut-off room of non-combustible construction.

Consult the MIT EHS Office Industrial Hygiene and Safety Programs if further assistance is needed.

Electrical

Include the following electrical features to control compressed gases within the laboratory:

1. Consider including an 'Emergency Gas Shut-Off' button to terminate the gas flow and shut off any research equipment. Consider locating the electrical gas shut-off button adjacent to the laboratory exit.
2. Provide emergency backup power for hazardous gas cabinet enclosure exhaust fans, alarms, and other system components.
3. Confirm that electrical fixtures in flammable and pyrophoric gas storage rooms conform to NEC Class I division 2 requirements
4. Cylinders and piping containing flammable or pyrophoric gases should be grounded if the buildup of static electricity could present an ignition hazard.

Testing Manifolds and Piping

Design specifications should include the following requirements for testing:

1. Before use, systems should be evacuated, vacuum tested, and pressure checked with inert gas at pressures two to three times anticipated working pressures. Systems should be leak tested with helium or nitrogen, dependent on gas to be used in system. (SEMI F1)
2. Testing certifications should be performed by a qualified vendor.

Codes, Standards & References

- 29 CFR 1910.103 – Hydrogen
- OSHA 29 CFR 1910.104 – Oxygen (bulk systems)
- OSHA 29 CFR 1910.111 – Storage and Handling of Anhydrous Ammonia
- OSHA 29 CFR 1910.253 Oxygen-fuel Gas Welding and Cutting
- OSHA 29 CFR 1926.350 Gas Cutting and Welding
- CGA-P1, Safe Handling of Compressed Gases in Containers (incorporated by reference into OSHA 1910.101)
- DOT 49 CFR, Parts 171 - 179
- Factory Mutual Global – Data Sheet #7-50 – Compressed Gases in Cylinders

- Factory Mutual Global – Data Sheet #7-55/12-28 – Liquefied Petroleum Gas
- NFPA Standard 45, Fire Protection for Laboratories Using Chemicals
- NFPA Standard 50A, Gaseous Hydrogen Systems at Consumer Sites
- NFPA Standard 51, Oxygen-Fuel Gas Systems for Welding and Cutting
- NFPA Standard 55, Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders.
- NFPA Standard 318, Protection of Semiconductor Fabrication Facilities
- NFPA Standard 704, Identification of the Hazards of Materials for Emergency Response.
- ANSI Standard B31.1, Pressure Piping
- ANSI Standard B57.1, Compressed Gas Cylinder Valve Outlet and Inlet Connections
- ANSI Standard Z48.1 – Method of Marking Portable Compressed Gas Containers to Identify the Material Contained
- SEMI FI, Specification for Leak Integrity of High-Purity Gas Piping Systems and Components, 2013
- SEMI S4, Safety Guideline for the Segregation / Separation of Gas Cylinders Contained in Cabinets
- SEMI S18-1102, Environmental, Health and Safety Guidelines for Silane Family Gases Handling
- Compressed Gas Association: http://www.cganet.com/
- OSHA Regulations: http://www.osha.gov/

3.2 Chemical Storage

Refer to section 17.2 EHS Thematic Folder for non-laboratory areas

Chemical storage for labs:

1. When designing a lab space, it is important to factor in the needs of the lab with respect to storage of chemicals. Their needs will depend, in part, on the extent of their chemical use

2. Labs are required to maintain a chemical inventory. The lab's chemical inventory is used to make sure the labs are within exempt quantities for the lab's building code classification and floor location.

3. The chemical inventory can also be used to get an initial idea of what the lab's chemical storage needs might be.

4. Chemicals should be stored in compatible groupings. Sufficient accommodation should be provided in planning lab space to assure that reasonable separation of incompatible groups of chemicals can be maintained.

5. In addition, the materials of construction for chemical storage areas should be compatible with materials to be stored, corrosion resistant, when needed, moisture proof, when needed, and easy to keep clean

Control Areas:

1. Control areas are spaces within a building, which are enclosed and bounded by exterior walls, fire walls, fire separation assemblies and roofs, or a combination thereof, where quantities of hazardous materials not exceeding exempt amounts are stored, dispensed, used or handled.
2. Where exempt amounts are not exceeded, control areas shall be used to store flammable and combustible liquids inside buildings. The design, construction, location and number of control areas shall meet the requirements of the Massachusetts State Building Code 780 CMR, and shall not exceed allowable amounts of hazardous materials per control area (as specified in 527 CMR). Maximum quantities may be increased within specified limits under the following conditions:
   a. When storage is in a building equipped throughout with automatic sprinklers in accordance with 527 CMR.
   b. If flammable materials are stored in approved cabinets, gas cabinets, fume hoods or ventilated cabinets.
3. The City of Cambridge requires that flammable liquid storage and Class I flammable liquids are not permitted below the first floor.
4. The number of permitted control areas per floor, the percent of allowable exempt quantities per control area, and the degree of vertical fire separation shall meet the requirements of 527 CMR.
5. Fire separation assemblies shall be in accordance with 780 CMR. Control areas are not permitted more than two levels below grade.
6. Floor and supporting structures for all floors within a control area shall have the required fire rating.
7. Control areas should be clearly delineated within the construction drawings.

Specific considerations:

1. Flammable Materials: should be stored in flammable storage cabinets. Many labs are designed with space under the fume hoods for storage of flammables. A lab with a large quantity of flammable materials may need additional cabinets for flammable storage, and the lab space will need to be designed to accommodate these cabinets. In some cases, it may be necessary to vent the cabinets. NFPA 30 provides guidance on how to correctly ventilate a flammable storage cabinet.

2. Storage of Volatile Toxics and Stench Chemicals: Ventilated storage should be provided for volatile toxic materials and/or stench agents. One option is vented flammable storage cabinets, or vented storage under fume hoods. Ventilation should be sufficient to prevent build-up of odor, but a large volume of exhaust air is not required

3. Storage of Acids: Ventilated, corrosion resistant storage should be provided for acids. In addition, organic acids need to be stored separately from oxidizing acids. There should be sufficient ventilated storage space to accommodate the specific needs for acid storage

4. Refrigerated Storage: In some cases labs may need appropriate space designed to accommodate refrigerated storage of some lab chemicals. There may be a need for special refrigeration equipment, and space will need to be designed to accommodate it, and electric utility needs should be factored in (appropriate outlets in good locations for equipment). Refrigerators and freezers for storing flammable liquids must be designed, constructed, approved, and labeled for that purpose. Design should consider the use of refrigerants with the least ozone-depleting potential available or non-regulated refrigerants. Equipment containing 50 pounds or greater of regulated refrigerants must be coordinated with EHS and DOF such that it can be added to the MIT Refrigerant Management Program database.

5. Shelving: Hazardous liquids need to be stored at eye level or lower. Shelving should be sufficient to accommodate such storage. Dry chemicals should be stored separately from liquids. Shelving should be sufficient to address this need as well

6. Under Sink Storage: Many times disinfectants and cleaning products are stored under sinks. Sink areas should be constructed of materials not likely to be damaged by storage of such products

7. Hazardous Waste Collection Areas: Ideally, waste collection areas should be ventilated, and be located in close proximity to lab hoods, where such waste is most likely to be generated. It is preferable not to have the hazardous waste storage occupying space in the lab hood. See section 3.3 in this document and section 9.1 in EHS Design for details on storage.

8. Compressed Gases: There should be appropriate accommodation for safe storage of compressed gases. Cylinders need to be properly secured. In some cases, there may be need for ventilated storage

9. Cryogens: There should be appropriate planning for proper ventilation in areas where cryogenic materials are being stored or used. It may be necessary to install oxygen depletion alarms in some spaces where cryogens are to be used or stored

10. Cold Rooms: Cold rooms should not be used for volatile toxic or flammable chemical use or storage unless they are designed for such use. Careful attention should be given to current activities in cold rooms when designing for chemical storage

11. Weigh Stations: It may be important to design space for location of dry chemical weighing areas that can be vented, either by air filtration or to the exhaust system.

Hazardous Chemical Inventory:

1. Architects, Engineers and Designers shall request a complete hazardous chemical inventory of chemicals from MIT (EHS will work with PI/ Department) that will be stored and used in the renovated space or new building in order to design the control areas. This is also needed for the flammable liquids, gases, and solids permits.

2. Hazardous chemical inventories (an inventory of potentially hazardous chemicals or products) must be completed prior to occupying new laboratories/workspaces, auxiliary spaces, and non-lab areas or leaving old or existing spaces.
3. The inventory is necessary to meet Massachusetts State Building Code, Cambridge Fire Department, Cambridge Local Emergency Planning Committee (LEPC) and Division of Homeland Security requirements. In addition, EHS uses the chemical inventory to ensure that adequate chemical storage and engineering controls (automatic shut-offs, fume hoods, etc.) are included in the project scope and the flammable storage permit/license quantities are kept updated.

Inside Flammable Liquid Storage Rooms:

1. Meet or exceed the latest edition of the following standards:

   a. NFPA 70, National Electrical Code.
   b. NFPA 80, Standard for Fire Doors and Fire Windows.
   c. Flammable and Combustible Liquids Code, NFPA 30.

2. Location: If desired design criteria quantities of stored flammable and combustible liquids exceed allowed quantities per control area, an inside liquid storage or cut off rooms (a room including one or two outside walls) is required. Inside storage rooms would have to meet all the requirements of H-2 or H-3 occupancy and cannot be constructed in basements.
3. Design: Inside storage rooms shall be constructed to meet the applicable requirements of 780 CMR and the Massachusetts Comprehensive Fire Safety Code and NFPA 30, Flammable and Combustible Liquids Code. Inside storage area shall not exceed 500 square feet. Cut off rooms exceeding 500 square feet shall have at least one exterior door approved for Fire Department access.
4. Fire Resistance Ratings: Fire resistance ratings for inside storage areas shall meet the minimum requirements of NFPA 30. In mixed use groups fire separation shall meet the separation specified in 780 CMR. Fire doors shall be installed in accordance with NFPA 80, Standard for Fire Doors and Fire Windows.
5. Fire Detection: All inside flammable storage areas shall be provided with fire detection system as per 780 CMR including flame detection.
6. Sprinkler Protection: Inside flammable liquid storage rooms shall be protected by an automatic fire protection system installed in accordance with 780 CMR. Secondary containment for indoor storage areas shall be designed to contain a spill from the largest vessel plus the design flow volume of fire protection water calculated to discharge from the fire-extinguishing system over the minimum required system design area or area of the room or area in which the storage is located, whichever is smaller. The containment capacity shall be designed to contain the flow for a period required by Cambridge Fire Department (20 minutes is a guideline).
7. Electrical: Electrical wiring and equipment located in inside rooms used for Class I liquids shall be suitable for Class I, Division 2 classified locations when concentration in

the area is in excess of 25% of the LEL. 527 CMR 12.00, Massachusetts Electrical Code and NFPA 70, National Electrical Code, provide information on the design and installation of electrical equipment.

8. Ventilation: Every inside room shall be provided with continuous mechanical exhaust ventilation system:

    a. Mechanical ventilation systems shall provide at least one cubic foot per minute of exhaust per square foot of floor area, but not less than 150 CFM (at least 6 air changes per hour).
    b. The mechanical ventilation system shall be equipped with an airflow switch or other reliable method which is interlocked to sound an audible alarm upon failure of the ventilation system and connected to BMS.
    c. The proportion of the exhaust ventilation shall be taken from the ceiling and the floor will depend on the density of the vapors expected from a spill.
    d. The location of both the exhaust and inlet air openings shall be arranged to provide, as far as possible, air movement across all portions of the floor to prevent the accumulation of flammable vapors.
    e. Exhaust from the room shall be vented directly to the exterior of the building without recirculation.
    f. All ducts shall comply with Massachusetts Building Code, 780 CMR.

9. Storage: In every flammable storage room, an aisle of at least 3 feet wide shall be maintained. Containers over 30 gallons capable of storing Class I or Class II liquids shall not be stored more than one container high.
10. Spill Control: Flammable liquid storage rooms shall be provided with spill control, secondary containment and drainage control. Please refer to OSHA 29CFR 1910.106(d)(4)(i).
11. Portable Extinguishers: At least one portable fire extinguisher, having a rating not less than 20-B, shall be located outside of but not more and 10 feet from the door opening into the liquid storage room.
12. Leak Detection: All flammable liquid storage rooms where storage, dispensing or pouring occurs shall have a supervised alarm to indicate a leak in the storage room.
13. Vapor Monitoring: Vapor monitoring will satisfy the leak detection requirements including:

    a. Flammable liquid storage rooms, where open use, dispensing or pouring will occur, shall be monitored for Lower Explosive Limit (LEL).
    b. The LEL alarm system shall activate on alarm points of 20% and 50% of the LEL. These set-points may need to be lower for liquids that are also toxic.
    c. The monitoring system shall be equipped with an audible and visual alarm indicator.
    d. The alarm signal shall be transmitted to a constantly attended station. The audible alarm shall exceed background ambient levels by 15db.
    e. The visual alarm shall be labeled.

f. The alarm sensors shall be located no higher than 12 inches above the floor.
g. Signage shall be posted outside the room. The signage shall include appropriate hazard warnings, as well as response instructions (e.g., "Do Not Enter if the alarm has been activated.") contact information and emergency phone numbers.
h. When the flammable liquid dispensing involves use of an automatic pumping system (as opposed to manual), the pump shall shut-down upon LEL alarm activation (or line leakage detection) to stop the flow of liquid.
i. The local authority having jurisdiction may require additional safeguards.
j. Exception: flammable liquid storage rooms where dispensing or pouring will not be conducted or when pouring/dispensing is done in fume hood in storage room.

14. Explosion Venting: Where Class IB liquids are in open use or being dispensed in excess of maximum allowable quantities, explosion venting shall be provided in accordance with 780 CMR.

Flammable Storage Cabinets:

Flammable storage cabinets must meet NFPA 30, Flammable and Combustible Liquids Code. These cabinets are used for storage of flammable and combustible liquids, and must have leak proof pans at the base of the cabinet to contain spills. These cabinets can be under fume hood cabinets or free standing. Cabinets must be labeled "Flammable - Keep Fire Away".

Flammable storage cabinets are not required to be vented for fire protection purposes. Venting a cabinet could compromise the ability of the cabinet to adequately protect its contents from involvement in a fire because cabinets are not generally tested with any venting. Therefore, venting of flammable storage cabinets used exclusively for non-highly toxic or non-highly noxious/odiferous flammable liquids is not recommended.

However, it is recognized that venting can be needed for other reasons, such as health and safety. Storage of highly toxic or highly noxious/odiferous flammable materials should be in a vented flammable storage cabinet. The cabinet should be vented directly to outdoors in such a manner that will not compromise the specified performance of the cabinet and in a manner that is acceptable to the Fire Department. The venting system should be installed so as to not affect the performance of the cabinet during a fire. Means of accomplishing this can include thermally actuated dampers on the vent openings or sufficiently insulating the vent piping system to prevent the internal temperature of the cabinet from rising. Any make-up air to the cabinet should also be arranged in a similar manner.

If vented, the cabinet should be vented from the bottom with make-up air supplied to the top. Mechanical exhaust ventilation is preferred and must comply with the Massachusetts Building Code, 780 CMR. Manifolding the vents of multiple storage cabinets should be avoided.

References:

Flammable and Combustible Liquids Code, NFPA 30

Massachusetts Building Code, 780 CMR

Flammable Liquid Approved Refrigerators: Any refrigerators used for storing flammable materials must be designed for such storage, with no internal electrical components.

Cold Rooms: Flammable, toxic, and combustible liquids that are volatile cannot be stored or used in cold rooms.

Grounding System: For dispensing of flammable and combustible liquids of more than one gallon from metal containers, grounding bars, cables and clamps shall be provided.

Acid Storage Cabinets:

1. Acid storage cabinets have corrosion resistant liners (powder-coated cabinets and cabinets with corrosion resistant liners) or be constructed from acid resistant materials like polypropylene. Under fume hood cabinets are vented into the hood using acid resistant pipes which lead to the interior of the hood. This is typically behind the baffle terminating in a location where good air volume will be drawn into the cabinet.
2. Acid storage cabinets can be used to store non-flammable materials that are toxic or odiferous. These cabinets can be under fume hood cabinets or free standing, exhausted cabinets. See section Chemical Storage for more information.
3. MIT EHS does not recommend cabinets with metal standards, clips, etc. because the metal will corrode. Molded plastic standards are an acceptable option for this application. The design of cabinet adjustable shelving should allow researchers to properly secure and level shelves. The supporting system should be stable and easy to readjust to another stable setting.

3.3 Hazardous Waste Handling Design Issues (section 9.1 EHS)

Three types of hazardous wastes may be generated in research buildings: radiological, biological and/or chemical. All are regulated by the Federal Environmental Protection Agency (EPA), the Massachusetts Department of Public Health (DPH) or Department of Environmental Protection (DEP). The requirements for handling these wastes are described below:

1. **Low Level Radioactive Waste:**
   a. Low-level radioactive waste will be collected from the research laboratories by EHS Office staff and temporarily stored in the designated room in the shipping/receiving area for transport to our waste management facility in NW13-141.
   b. A radioactive waste storage accumulation area (closet) on each laboratory floor is not necessary for this waste stream. A designated room near the shipping/receiving area (loading dock) of approximately 150 square feet for temporary storage of radioactive waste and for supplies for the radioactive waste program.

c. Access control via proximity card reader or electronic combination lock on the waste storage room door is required.

d. WiFi Internet access is required for uploading waste records at the storage location.

e. A lab equipped with a chemical fume hood is required for processing radioactive waste. Liquid and mixed chemical/radioactive waste are sampled and/or processed in the fume hood. A walk-in hood is desirable for bulking of radioactive liquid waste if this waste stream is generated.

f. The lab could be shared by the chemical waste management program especially the bulking procedures.

g. See recommendations for Chemicals below for additional requirements.

2. **Regulated Medical Waste (Biological):**

a. Biologically contaminated waste will be collected from the research laboratories by EHS Office staff and temporarily stored in the designated storage rooms in the shipping/receiving area for transfer to our regulated medical waste vendor for final disposal.

b. A waste storage accumulation area on each laboratory floor is necessary for laboratory buildings that generate copious amount of biological waste. A designated room near the shipping/receiving area (loading dock) of approximately 150 square feet for temporary storage of biological waste and for supplies for the biological waste management program.

c. Access control to the floor level and building level waste storage facilities via proximity card reader or electronic combination lock is required.

d. WiFi Internet access is required for uploading waste records at the floor and building level storage locations.

e. Several rooms or cage areas equipped with shelving are required for storage of supplies used in the biological waste management program. This rooms would be strategically located throughout the campus.

f. In vivariums, freezer/cold room storage capability is necessary for carcasses storage and packaging in final shipment containers. A designated cold room near the shipping/receiving area (loading dock) of approximately 100 square feet for temporary storage of pathological waste prior to collection by our regulated medical waste vendor. This room should be equipped with a raised floor and an alarming temperature sensor reporting through BMS.

g. See recommendations for Chemicals below for additional requirements.

3. **Chemicals**

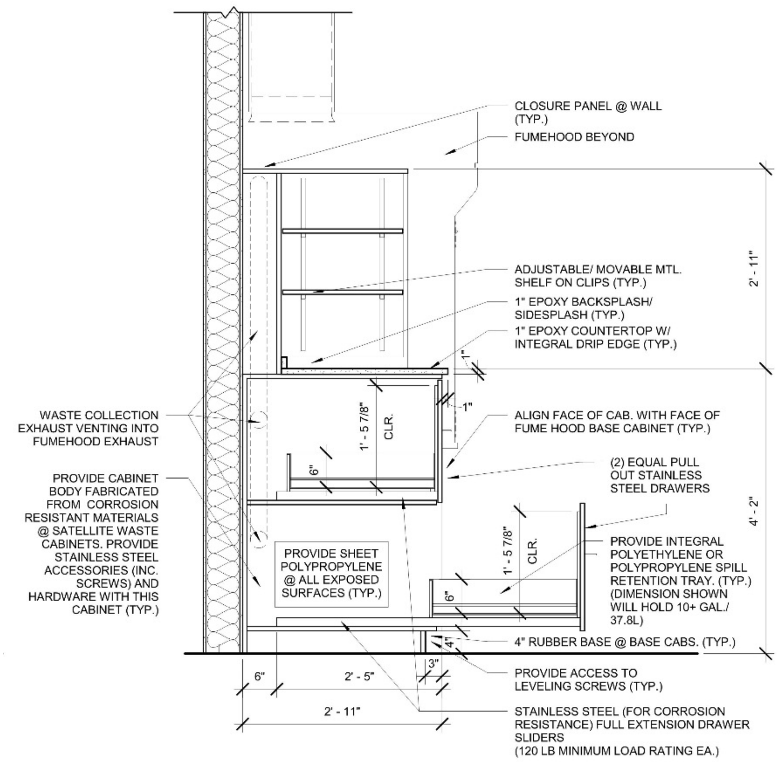
a. Where chemicals are used in research, hazardous chemical waste will be generated and will need to be stored prior to shipment for disposal.

b. MIT EHS has requirements for 3 phases of waste storage at the Institute; within the lab (Satellite Accumulation Area - SAA), common to the floor (mini Main

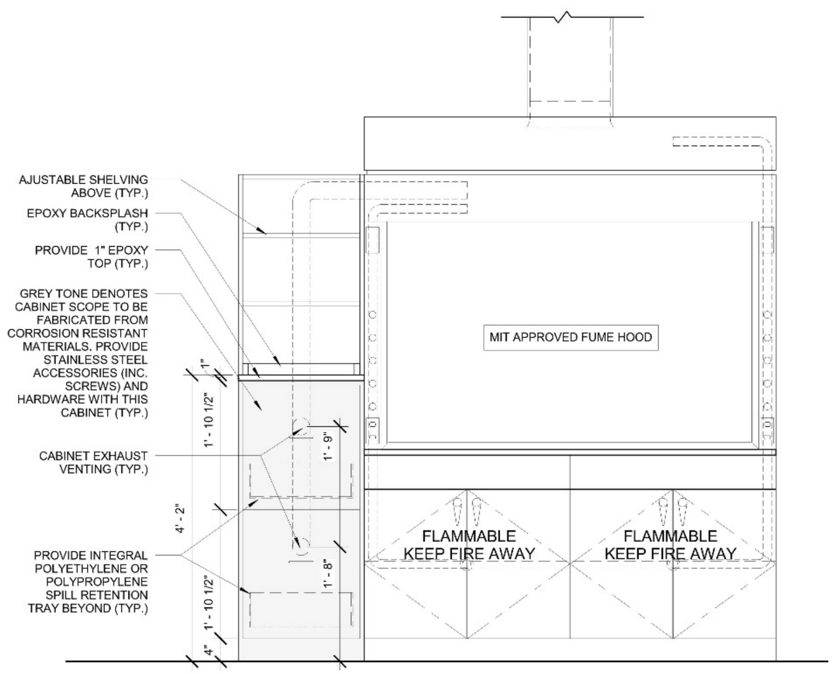
Accumulation Area - mini-MAA) and central storage area (MAA).

i. **Satellite Accumulation Area (SAA) within the Lab**:

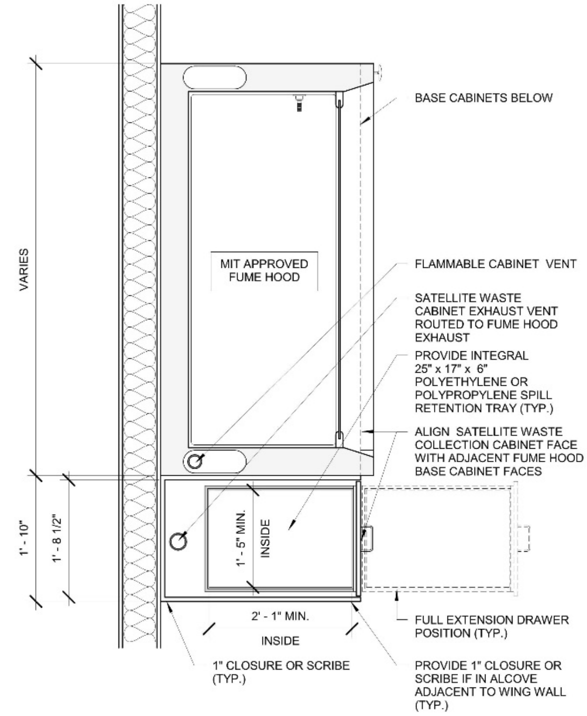
- Hazardous chemical waste must be stored properly at the point of generation, i.e. within the lab close to where the research is conducted.
- Space should be designed to store containment bins for bottles ranging in size from 50-mL to 30-gallon drums, depending on the research.
- These locations must be labeled with SAA identification stickers/signs provided by the EHS Office.
- A vented chemical storage cabinet may be used as an SAA inside a laboratory provided it is compatible with the waste to be stored, and has proper signage. Contact EHS to assist with this option.
- **Example 1 SAA for multiple chemicals** (currently used in Building 76 includes):
    - Fume hood cabinet drawers may be used for SAA collections.
    - The overall cabinet needs to be sturdy enough to support the weight of the hazardous waste required to be held.
    - Drawers must be able to safely support 120lbs (minimum) each drawer. The draw slides must be extra heavy duty, corrosion resistant stainless steel.
    - They Drawer slides should allow for full drawer extension – with a load rating of 100lbs (minimum) per slide.
    - Cabinet finish should be of same grade and quality of high quality metal lab casework used in lab renovations.
    - All screws and fasteners should be 316 SS machine screws or better for strength and chemical resistance.
    - Cabinets should be well ventilated to dedicated exhaust.



Section: Example 1 SAA for multiple chemicals/ Waste Collection Cabinet



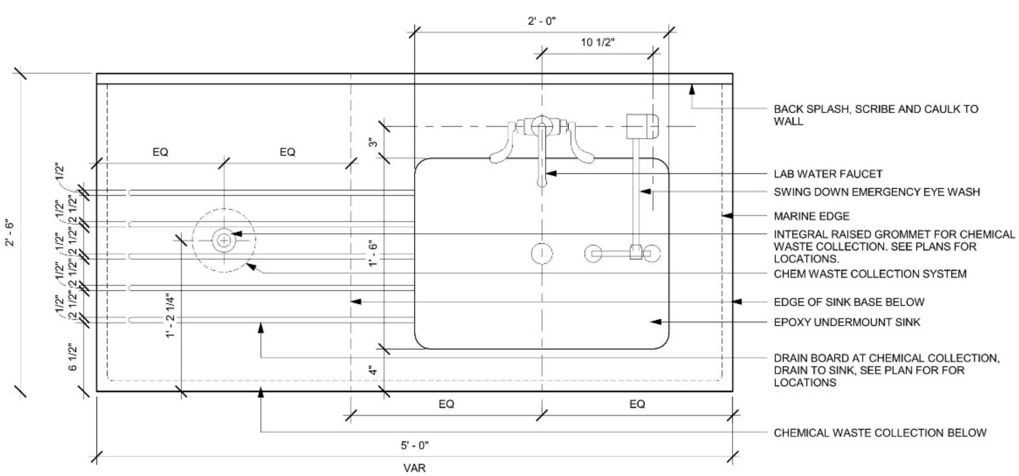
Elevation: Example 1 SAA for multiple chemicals/ Waste Collection Cabinet



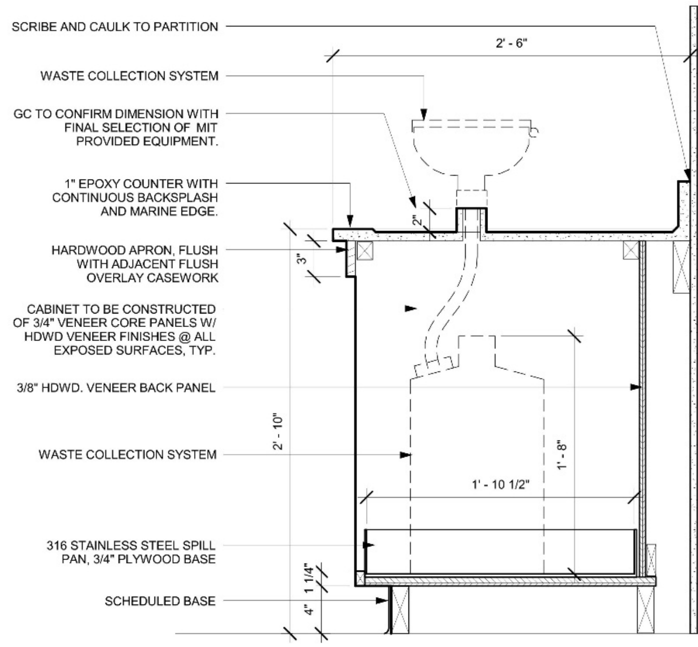
Plan Section: Example 1 SAA for multiple chemicals/ Waste Collection Cabinet

- **Example 2 SAA Chemical Hazardous Waste Collection Station** for single chemical/class materials (example: Acetone glass-washing) inside and outside of fume hoods:

    1. Secondary containment **adjacent to sink location**. Refer to typical details below:

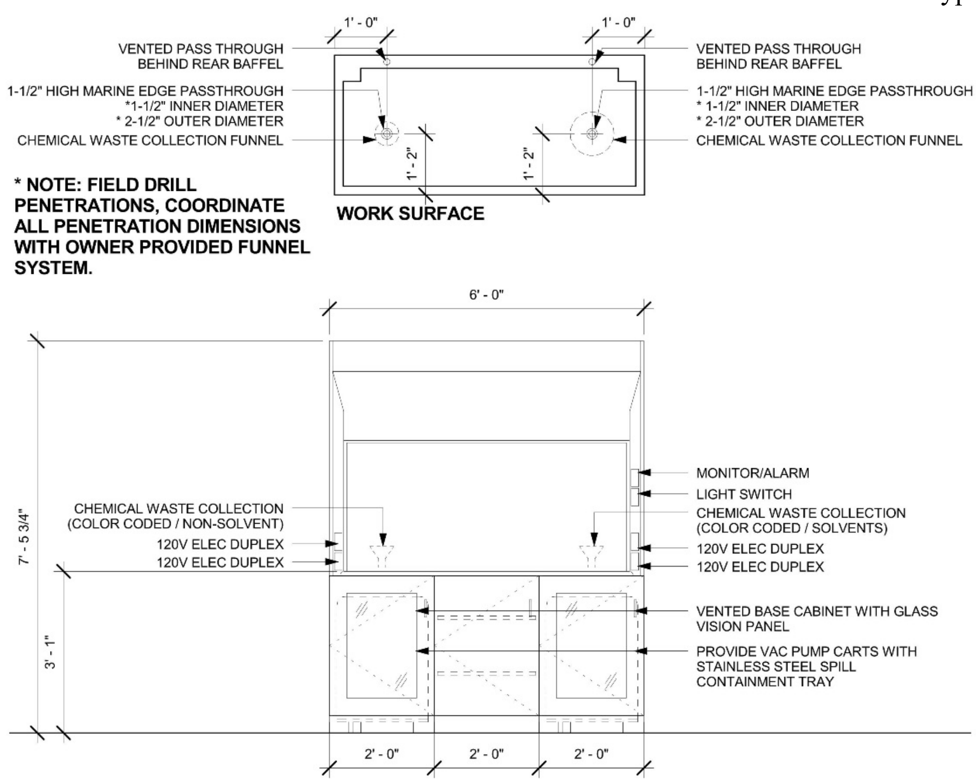


Lab Sink Plan: Example 2 SAA Chemical Waste Collection Station.



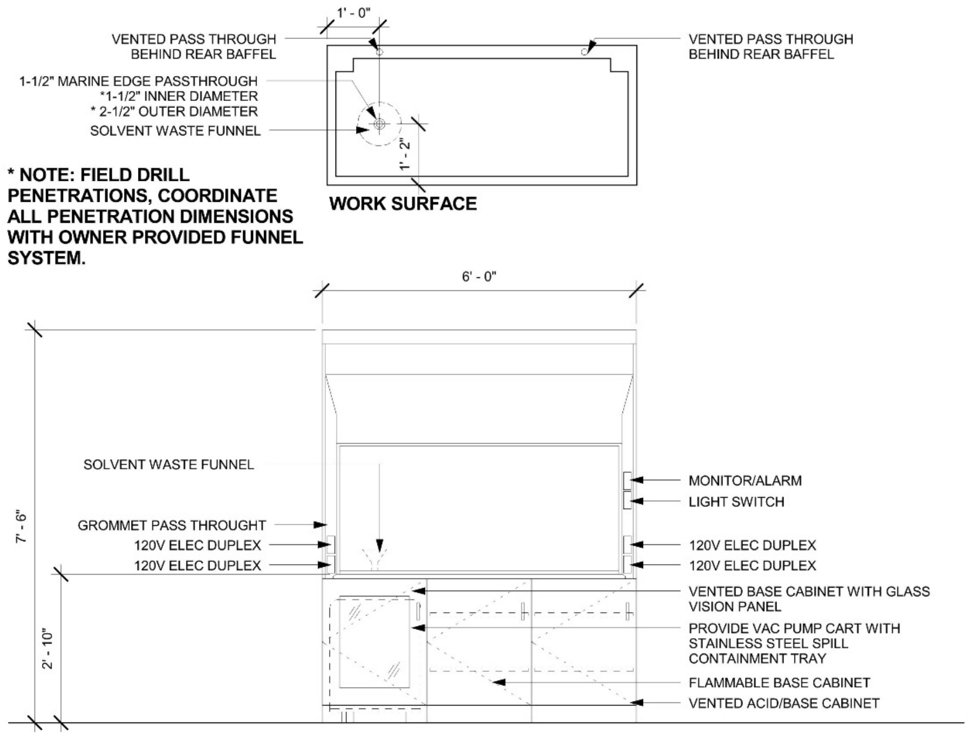
Section: Example 2 SAA Chemical Waste Collection Station.

2. Collection station **within fume hood**. Refer to typical details (over):



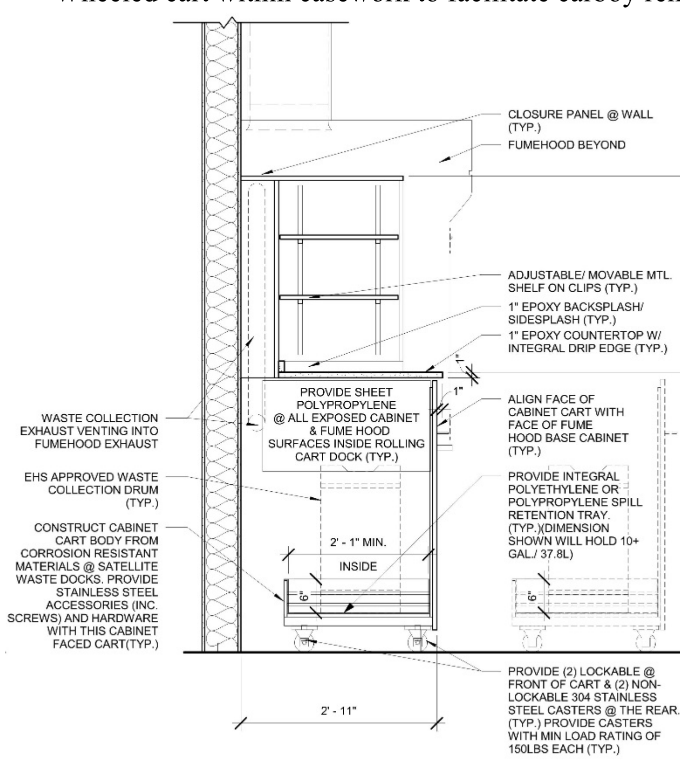
Plan & Elevation:

Typical Double Fume Hood Chemical Waste Collection

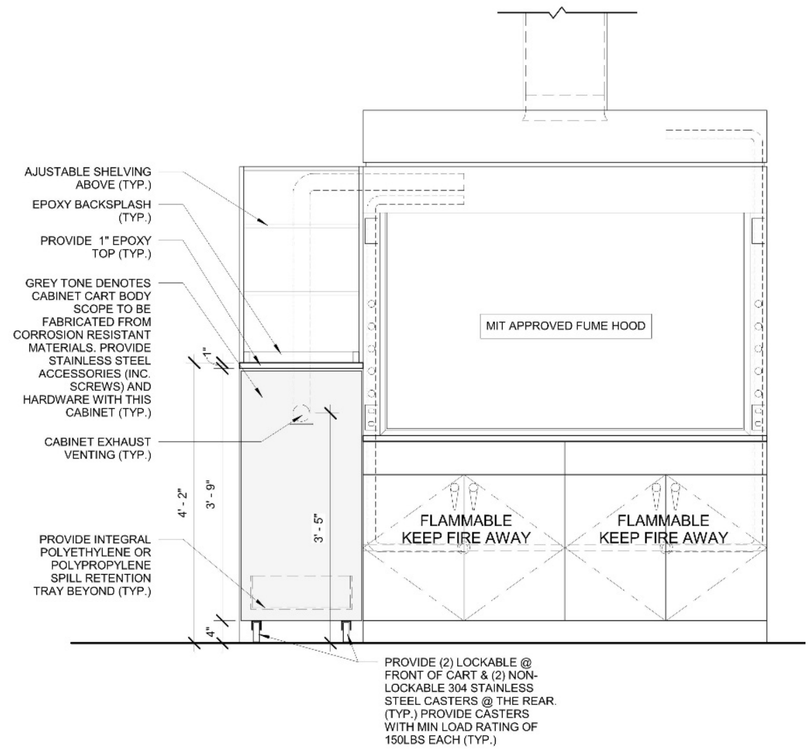


Plan & Elevation: TYP. Single Fume Hood Chemical Waste Collection

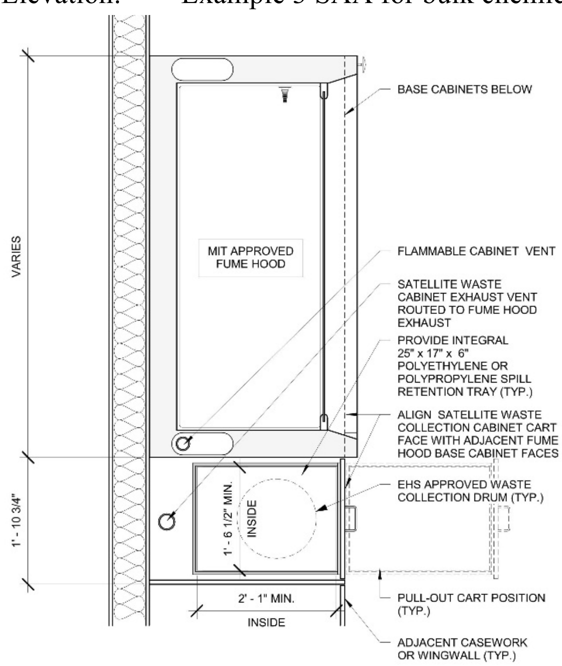
- **Example 3 SAA for bulk collection** (example: Xylene in a carboy)
  - Wheeled cart within casework to facilitate carboy removal.



Section: Example 3 SAA for bulk chemicals/ Waste Collection



Elevation: Example 3 SAA for bulk chemicals/ Waste Collection Cabinet



Plan Section: Example 3 SAA for bulk chemicals/ Waste Collection Cabinet

ii. Mini-Main Accumulation Area Common to the Floor:

- The need and size of the following location will depend on the type of research conducted, volume of chemicals used and amount of waste generated within the building or at the floor level.

- The recommended design is to provide one storage area per floor for chemical waste, controlled by EHS but accessible to the occupants on the floor, card access to these locations is preferred for this reason.
- To accommodate these containers, while maintaining compatibility separation, a room suitable to contain at least 1-2 standard safety cabinets (43"x34"), and space for supplies and spill materials is needed. Actual room size is dependent on research and expected waste volumes.
- The room need only be about 120 square feet and will need to be ventilated.
- Flooring shall be chemical resistant and resistant to leaks. No floor drains permitted.
- This room will need access to safety equipment; such as, an eyewash, safety shower, internal emergency communication system, portable fire extinguisher and automatic sprinklers or water spray system.
- Provide heavy-duty shelving units for storage or chemical storage cabinets.
- Access to freight elevators and the loading dock will be necessary for the movement and shipment of the chemical waste generated onsite.
- Signage for the floor areas will be provided by the EHS Office.

iii. Central-Main Accumulation Area:

- Depending on the location and type of research building proposed, EHS should be consulted regarding the need and possible location for one main storage area for the building for packaging and storage of waste prior to shipment.
- In the event a new Central-MAA is needed, the storage area should be located within 50 feet of the property line on the ground floor near the loading dock.
- Depending on the materials used in the building and anticipated waste to be generated, the space should be ventilated, be at least 500 square feet in size, and should meet the requirements for an inside flammable liquid storage room.
- This room will need an eyewash and emergency shower installed, automatic sprinklers or water spray system, access to a portable fire extinguisher, spill materials and internal communications or alarm system.
- Provide a sink for personal hygiene purposes.
- There may be a need to provide a walk-in hood with a grounding bar and equipment for bonding and grounding, in the event large quantities of solvent are used within the space and the location is not part of the contiguous campus.
- Secondary containment for the room is required.

- Provide shelving units for storage or chemical storage cabinets.
- Size the door to provide appropriate width for moving chemical cart and drums in and out.
- This room must be card accessible and managed in the same way as the central waste accumulation areas on campus (24-038 and 76-190).
- Note: Due to regulatory requirements, Class I flammable liquids cannot be located below the ground floor (basement and sub-basement).
- WiFi internet access will be required for uploading inspections and inventory data for shipment purposes.
- The floor will need an epoxy coating.

3.4 Accessibility

Emergency eyewash and shower equipment that meets the ADA requirements should be installed when new buildings are constructed or when the building is renovated. Designers of new labs should refer to the Massachusetts Access Architectural Board (MAAB) guidelines for approach and reach. 521 CMR 6 and 521 CMR 12.00 Educational Facilities

*New emergency shower installations should be ADA compliant.

Any laboratory serving the undergraduate student population shall be provided with at least one (1) ADA accessible fume hood and sink.

1. Within laboratories, it is preferable to specify the accessible stepped/ tiered laboratory sink configuration with the deeper well beyond the shallow accessible portion of the sink.
2. We recommend a convertible sink base, where the doors and shelf fold away, or are removable, to provide ADA accessible clearance.
3. Incorporate and coordinate accessible sink fixtures such as blade faucet activation and barrier free eyewashes. The offset ADA accessible fixtures allow for weekly testing within the smaller dimensions of an accessible sinks.

3.5 Green Lab Design

The following areas should be reviewed with the project design team and occupants of the lab space to determine opportunities for sustainable design in an effort to increase long term cost savings and efficiencies once the space is occupied:

1. **Energy:**

    a. Efforts should be made to reduce the number of fume hoods and bio safety cabinets where possible.
    b. Fume hoods with lower face velocity and sash restriction are preferred by the EHS Office, refer to Section 3.2, Laboratory Chemical Hoods, of the EHS Design Guidelines for specific requirements.
    c. In situations where variable volume fume hoods may be considered for hibernation (shutting them off for periods of time), the correct corresponding

HVAC valves and controls must be installed.

d. Energy saving stickers, i.e. "Lower the Sash" information should be posted prior to the use of the lab.
e. When 3 or more hoods are located in a laboratory, a best practice is to provide a reminder to users to make sure sashes are closed. One way to do this is to provide an LED display of the total exhaust from the lab near the lab exit.
f. Task lighting and light switches for equipment and local lights should be offered, with reminders to turn off the lights when not in use.
g. Plug load metering devices should be installed throughout the lab in better inform occupants of the energy used by equipment.
h. Methods to provide user feedback on building systems and energy use should also be considered.
i. Labs moving into renovated or newly constructed space should be encouraged, and aided by the project, to purchase energy efficient equipment wherever possible.
j. Placement of cold storage units should be given consideration to minimize the heat generation within the lab space. Wherever possible, UTL freezers should be placed near exhaust units to reduce the amount of heated air that will then need to be cooled by the HVAC system. Ideally these units should be housed in an equipment corridor that has cooling provided by independent cooling equipment and not by single pass air. This strategy effectively decouples the ventilation air requirements from the equipment cooling requirements.
k. If possible, the co-location and consolidation of cold storage units in a common location (aka freezer farm), is a proven strategy to minimize cooling energy use. This strategy also has the side effect of maximizing usable space within the primary laboratory.
l. Consideration for Energy Efficient Autoclaves should be given where autoclaves are in use. Refer to Section 3.3.14, Autoclaves, within the EHS Guidelines for more details. Suggested vendors include Priorclave North America and Consolidated Sterilizer Systems.

2. **Water:**

a. Consider the use of foot pedals at sinks to ensure water is not left running when the user walks away from the sink. Also consider the installation of low-flow aerators on faucets to control water flow and reduce water consumption.
b. Energy efficient autoclaves and water misers for autoclaves should be reviewed for use within a lab to reduce the amount of water consumed by this type of equipment. A water miser is a device used on sterilizers or autoclaves to monitor the temperature of the system and apply cold water only when needed. Using this type of device can save 40-50 gallons of water per hour. Consolidated Sterilizer Systems offers a WaterEco Series sterilizing system or autoclave that can save over 1000 gallons of water per day.
c. EHS prohibits the once-through or single-pass cooling technique. Refer to MIT

Design Guidelines section on plumbing for specific information and alternatives.

3. **Equipment:**

    a. Laboratories use a lot of equipment. As indicated above, researchers should be encouraged and aided by the project to bring energy and water efficient equipment into a newly renovated space when possible.
    b. Shared equipment stations should be explored during the design phase, as well as, the placement of equipment throughout the space.
    c. The installation of metering devices to monitor the water and energy use of equipment or timers to allow for equipment to be turned off when not in use, should be discussed as well.

4. **Chemical Storage and Sharing Capabilities:**

    a. Reduce the depth of chemical storage and shelving units in order to increase the visibility of the lab's chemical inventory. This will enable better chemical inventory management practices, which save the lab time and money.
    b. During design, discuss the option of a shared chemical stockroom that can be safely accessed by lab and departmental members.

5. **Waste Management:**

    a. Refer to General Waste Handling, of the EHS Guidelines for suggestions regarding recycling stations within the lab and throughout the building.
    b. Consideration for waste management at the loading dock level, as well as, access to the central campus collection points will be key to successful cost savings measures and reduction of inefficiencies over time.

3.6 Integrated Pest Management

Integrated pest management for lab design is complex. In spaces where biological or animal work will take place attention to pest management must be a priority. Before starting work a pest inspection of the space should be conducted, by the pest management vendor and design team, to control or eliminate any pest and to seal any pest access points in to the space.
After the work is concluded a follow up a pest inspection of the space should be conducted, by the pest management vendor and design team to ensure all pest access points have been blocked with suitable materials.

Focus for both inspections should be:
- Perimeter of the room.
- Duct access points between spaces.
- Floor drains.
- Closets and cabinets.
- Electrical systems.

- Dropped ceilings.
- Heating and cooling systems.
- Animal facilities for housing, cage washing, surgery, bedding disposal, and food storage.
- Sewer systems.

Doorways grant access to people but also pests; the gap between a door and a door jamb should be 1/4 of an inch or less.

4. LAB ENVIRONMENTAL REQUIREMENTS

4.1 Controls

Temperature Control

As sustainable energy targets become more and more stringent, designers are looking for alternate methods to reduce energy use. Building on the individual user defined temperature control that is becoming standard practice in today's science buildings, a re-evaluation of acceptable temperature variances and ranges are under discussion. From an EHS point of view, the science may demand a tighter tolerance in laboratory spaces than in office, conference, and collaborative spaces. These low-risk spaces may become opportunities for wider temperature variations, or possibly natural ventilation under specific conditions.

In laboratory environments, smaller temperature variation may be allowable during turn-down cycles (for example late night), but due care has to be taken to work within the parameters of any equipment or specimens that may occupy the laboratory 24hr/day 7 days/week. For example: certain equipment, such as -80 freezers, may be amenable to reduced temperatures (during a heating cycle) but not to higher temperatures. (Due to their overwhelming reliance on air cooled compressors in lieu of the much rarer water-cooled variety.)

Humidity Control (See HVAC Division 23)

4.2 Ventilation (section 16.2 EHS)

Air Changes

All air change rates are to be determined by the use and hazard level, in association with MIT EHS. Laboratory ventilation systems designs are to ensure that chemical fumes, vapors, or gases originating from the laboratory are not recirculated. The design should ensure that air pressures in the laboratory work areas are negative with respect to corridors and non-laboratory areas of the laboratory spaces except for positive pressure cleanrooms; or when doors are opened, fume hood sash positions are changed, or other short-term temporary activities that would affect static pressures. (The other exception is in a designated electrically classified hazardous area with a positive air pressure system as described in NFPA 496: Standard for Purged and Pressurized Enclosures for Electrical Equipment.) NFPA 45: Standard on Fire Protection for Laboratories does not specify an ACH rate, but rather provides the general statement that "laboratory ventilation systems shall be designed to ensure that fire hazards and risks are minimized." This means that you need to consult the chemical consultant on the project for the proper storage and dilution rates. ANSI Z9.5 states that "Air changes per hour is not the appropriate concept for designing contaminant control systems." however, it suggests up to 10 ACH for fugitive emissions and odors. This standard is the most comprehensive and is to be followed during any laboratory design. This standard does not prescribe an ACH rate. It simply states that the specific room ventilation rate shall be established or agreed upon by the owner or his or her designee. All contaminants should be controlled at the source.

Special local exhaust ventilation systems, such as snorkels, are to have sufficient capture velocities to entrain the chemical being released. It is important to not underestimate what is required to provide proper capture velocities. These calculations are in the ACGIH Industrial Ventilation guide and can range from 75 to 2000 fpm, depending on the configuration and process.

1. **Overall HVAC Design Approach:**

    a. MIT EHS and Department of Facilities agreed back in the late 1980's on a minimum of 6 air changes per hour for laboratories with chemical, biological, or radiological hazards.
    b. EHS can require a higher air change rate if they believe the hazard level requires it.
    c. EHS's approach, generally is to first try to eliminate or reduce the hazard, and then capture airborne hazards with local exhaust controls (chemical hoods, biosafety cabinets, enclosures, capture hoods) and not to rely on general exhaust ventilation rates to control hazards.
    d. Designers should work with researchers and EHS to determine local exhaust requirements, then determine if energy conservation measures like variable air volume hoods are feasible and appropriate, and then finally calculate air change rates provided by the lab ventilation system.
    e. Previously, MIT has not made a distinction between air change rates for occupied and unoccupied labs. The Koch Institute uses occupancy sensors to reduce air change rates to 4 ACH when the lab is unoccupied. This approach should be evaluated on a case-by-case basis to improve energy efficiency while maintaining laboratory safety. It is best to handle heat load with a recirculating system like a fan coil or chilled beam rather than single pass air. These units only recirculates within the local lab environment.
    f. If air change rates for the lab are high (greater than 15 ACH), special air supply distribution systems may be necessary to ensure hood containment is not adversely affected by cross drafts.
    g. Designers should ensure that densely populated fume hoods, as in various forms of chemistry, do not experience air starvation and loss of containment in the event of a power failure. This fume hood make-up air starvation can be exacerbated if the supply air handlers supplying these fume hood dense spaces are not on standby power. Two typical methods of addressing this make up air starvation are:

1. Place the part of the system supplying these hood dense spaces on standby power.
2. Have mechanically actuated make up air ventilation available during power outages. Example: Emergency actuated windows (with bug screening).

2. **Calculation Guideline:**

a. ACH = Q, cfm (exhaust or supply whichever is greater)/V, cu ft. (Room Volume) x 60 min/hr.
b. In unusually tall spaces, the ceiling height is generally assumed to be 10 feet for purposes of the calculation. In general, the empty room volume is used and no accounting is made for volume occupied by equipment.
c. Discuss your situation with EHS if you believe the design you are working on should follow another approach. ACH (max and min if VAV) should be calculated for each new lab design and be included in the HVAC portion of the mechanical drawings.

3. **Labs without Chemical, Biological or Radiological Hazards:**

a. In general, the 6 air changes per hour ventilation rate does not apply to areas where chemical, biological, or radiological hazards do not exist.
b. Sometimes these facilities are still considered a laboratory but ventilation rates should be based on 20 cfm of outside air per person (based on number of people routinely in the space) unless other considerations in the space (heat load or other equipment requirements) dictate a higher rate.

4. **Non-Lab Areas with Hazards:**

a. When designing ventilation systems for machine shops, studios, and other types of non-lab areas with hazards, consult EHS on the HVAC system approach rather than relying on a standard ACH approach. EHS will need to work with users of the space to determine if local exhaust is required and if air cleaning is necessary. If general exhaust only is provided for these areas, EHS may need to articulate the restrictions on work or required work practices that exist for the area.

5. **Process for Lab Ventilation Optimization in Existing Labs:**

a. In some cases lab recommissioning leads to a lab ventilation optimization program in existing labs in a building or DLC.
b. This process must include a risk assessment step conducted or reviewed by MIT EHS. This risk assessment process will help determine if the lab ventilation system needs to be changed to support the current research needs or to correct HVAC issues.
c. These programs place a particular emphasis on reducing exhaust rates through the laboratory. Including the risk assessment step in this process helps ensure that changes are done without adversely impacting lab safety.
d. The risk assessment process also provides a mechanism for researchers to be

involved in reviewing lab ventilation optimization recommendations.

Pressurization for Lab Spaces and Buildings

In an overall building design it is appropriate to keep the building at a slightly positive pressure. This eliminates unwanted infiltration.
However specific laboratories may require pressure control requirements with respect to other spaces (e.g., corridors). For example it may be positive pressure for clean rooms, or negative pressure for most laboratories, HVAC systems must be designed to satisfy space pressure needs under all conditions of operation.
In general a 10% difference between supply and exhaust air is recommended to maintain a lab under negative pressure. In special cases there may be more stringent requirements requiring pressure control strategies.
There are following pressure control strategies that can be used. Architect/Engineering team should review specific applications with MIT EHS department.

1. Space pressure control
2. Flow totalization
3. Flow synchronization
4. Constant-volume reset control

Detailed description is provided in chapter 29 of Guidelines for Laboratory Design, John Wiley & Sons (DiBerardinis et. al. 2010)

Air Flow/Diffusion

Airflow distribution within laboratories need to consider several factors that can directly impact the safety and comfort of the occupants. While energy efficiency is a prime factor in the design of the ventilation systems within the laboratory, the following are examples of additional considerations vital to the successful design of a laboratory environment.

1. Fume Hood placement within the laboratory. Please refer to the "Fume Hood" section in section 7.1 of this document.
2. The location of supply air diffusers should also be taken into consideration.

Directional Airflow (delta P)

Directional airflow must be sustained 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.

Lab Ventilation Setbacks

If certain EHS parameters are met regarding signage identifying the current state of the laboratory ventilation systems, motion detectors can be utilized to activate full active laboratory ventilation by zone during off hour "turn-down" periods. This methodology can counteract the tendency to run all laboratories 24-hrs a day, 7 days a week in order to allow for the work flexibility of the users. In order to enhance the sustainable goals of the institution, using smart technology to allow for reduced ventilation rates during periods when the laboratory is unoccupied, can realize significant energy savings. If this strategy is pursued, clearly identifiable signage displaying the ventilation status of the lab is required to allow for off hour laboratory users to confirm that the system has detected them and has increased the ventilation rate to full occupied levels before beginning work in the laboratory.

Other than CO_2 monitoring in classrooms and conference spaces, NO other "facility system air monitoring" (contaminant sensing) system is to have demand control over the HVAC system in a laboratory environment.

4.3 Specialty Local Exhaust Ventilation (SLEV)

Meet or exceed the following standards:

1. American Conference of Governmental Industrial Hygienists (ACGIH). Industrial Ventilation: A Manual of Recommended Practice, most current edition
2. Semiconductor Equipment and Materials International. Facility Standards and Safety Guidelines, most current edition
3. ANSI/AIHA Z9.5 Laboratory Ventilation

Specialty local exhaust ventilation is exhaust ventilation that is designed for a specialized laboratory process. There are many types of SLEV that may be needed in laboratories depending upon the nature of the chemicals, and processes in use in the lab. Because of this large variety, it is imperative that the EHS Office be consulted during design review to specify air flow, face velocity at openings, and physical design. It is important that the final design be adequate to control contaminants but not waste energy by incorporating excessive or unnecessary air flow.

MIT currently has 2000 separate pieces of local exhaust ventilation serving laboratory equipment (in addition to fume hoods). The EHS Office measures the performance of the ventilation annually for high priority SLEVs and every 3 years for regular priority SLEVs.

Some typical SLEV devices include the following:

1. Chemical storage cabinets for flammables and for corrosives are discussed in above in Flammable Storage Cabinets and Chemical Storage Cabinets

2. Snorkel exhaust with small diameter plastic canopies can be used for work will small amounts of low toxicity solvents and adhesives on the open lab bench

3. Plain open ducts are can be used to exhaust a variety of lab processes such as vacuum pumps, pressurized glove boxes using nitrogen or argon, and exhaust from laboratory analytical instrumentation. For vacuum pumps, a typical design airflow is 50 cfm (a minimum of 25 cfm above the maximum pump down airflow of the pump). Vacuum

pumps containing oil should have an oil filter in place (available from the manufacturer) to prevent oil mist from being drawn into the exhaust system. It is recommended that the connection between vacuum pump and duct be open and not sealed so that oil is not pulled from the pump into the exhaust system. For glove boxes, small amounts of continuously flowing nitrogen and argon may be used to pressurize them. A 4-inch duct exhausting 50 cfm can handle exhaust from several glove boxes. A method for securing vacuum and other exhaust hoses inside the exhaust duct should be provided. This can be a cross-piece at the bottom of the duct, or adjustable set screws that are positioned no more than 4 inches from the bottom of the duct. Valves and controls should allow these hoses to be inserted into the duct's exhaust air stream at least 6 inches.

4. Small canopies in the lab can be used to exhaust heat from glassware dryers, solvent vapor from gas chromatography autosamplers, and heat and gas emissions from atomic absorption furnaces. The size of the canopy will depend on the dimensions of the equipment and should be designed according to the guidelines of the ACGIH Industrial Ventilation Manual (see References below). Large canopies require a large amount of exhaust to be effective and often an enclosure is a more efficient capture method and requires lower airflow cfm. Stacked ovens should have a bottom shelf to keep lower oven off the floor and shelves should be perforated to allow heat to rise to capture hood above

5. Gas cabinets are required for toxic gasses with an NFPA Health Rating of 3 or 4. In general, the flow rate provided to the cabinet should be specified by the manufacturer. A typical flow rate for a two-cylinder cabinet is about 275 cfm. At minimum the Semiconductor Industry and NFPA requires 200 feet per minute face velocity at the open access port.

6. Specialty equipment enclosures are often provided by the manufacturers. Manufacturer's recommendations are generally followed in this case with review by the EHS Office. For semiconductor equipment, SEMI (Semiconductor Equipment and Materials International) requires that semiconductor tool cabinets be tested with tracer gas for containment of gas leaks and that the report be furnished to customers. This report should be requested for all semiconductor equipment purchased

7. Other specialty equipment enclosures may be designed in house through the Central Machine Shop or local vendors. EHS will evaluate designs with respect to containment, airflow, materials of construction, physical dimensions, and location of access ports. For enclosures for processes using highly toxic materials, some guidelines include an airflow of ten air changes per minute with 100 fpm face velocity at any opening. Openings for air to enter the enclosure (of roughly the same area as the exhaust duct) must be provided so that there is continuous air flow through the enclosure to allow purging of any contaminants

8. Slot exhausts are used in animal areas for the administration of anesthesia and other procedures. A convenient size is 3 feet in width containing 3 slots having slot velocities of 750 to 1000 fpm. Total airflow is typically 300 cfm. Exact physical dimensions can

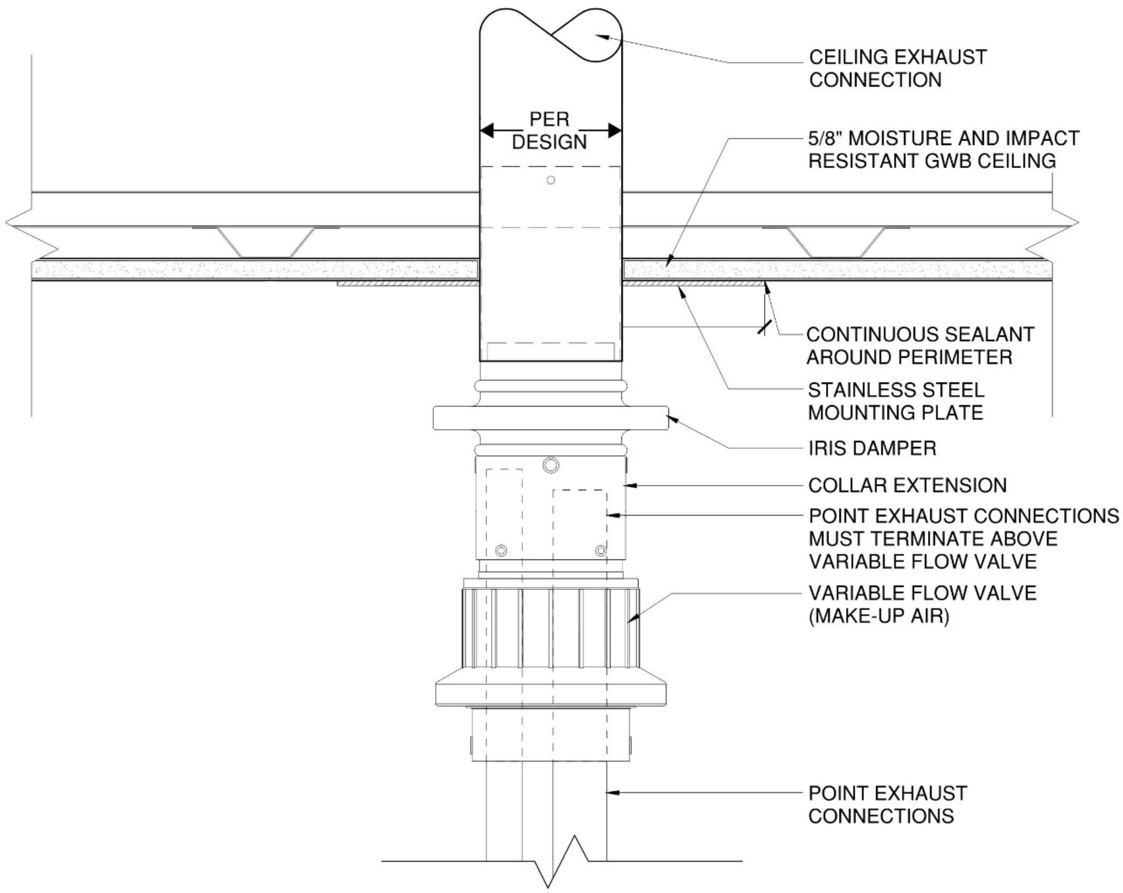
be obtained from the units in DCM in the Koch Building. Plastic sides must be installed on each slot unit. Sometimes a top is installed also depending upon the procedures being performed

9. Machine shop and welding area local exhaust ventilation should be designed using the templates provided in the ACGIH Industrial Ventilation Manual

Typical Equipment Thimble Connection:

In situations that require the exhausting of contaminants from pieces of equipment with variable flow rates (ex. vacuum pumps), the following detail may be applicable:

1. Note: the following detail is conceptual, and any application must be designed and vetted by the project's HVAC engineer, and MIT's EHS/ Facilities departments for the specific location in question.



4.4 Lighting

Lighting Amount

If the design team chooses to light the aisles in lieu of the bench edge in the interests of lighting efficiency, the design team is to ensure that 70fc can be achieved at the benchtop (typical 36" a.f.f.) without shadows being cast by the user of the benchtop. The use of task lighting and alternate reagent rack designs are acceptable alternate solutions to eliminating shadows.

Lighting Control

Controlling the light quality, intensity, color, and schedule are all potential variables when designing lighting in laboratories. While sustainable features can be somewhat automated to accommodate a series of sustainable goals, the science requires that the science users have an ability to override those systems in specific instances. A selection of lighting examples are listed below:

1. Basic Bio-Laboratory Bench lighting controls can utilize daylight harvesting techniques in order to save energy and reduce glare at the work surface while maintaining at least 70-75 FC.
2. Electrophysiology: A locally controlled, non-ballasted (ex. LED), dimmable fixture at the rig site within the light darkened zone with multi-zoned switchable general lighting. (the ballast interferes with the RF shielding)
3. Imaging: The same as Electrophysiology except without the RF frequency restrictions on the dimmable fixture.
4. Vivarium holding room: a programmable multi-bulb fixture that can be switched between standard white light and “rose chocolate” red light. The white lighting should be capable of offering 2 levels of light, 30-35 FC at 3’-0” and 70-75 FC at 3’-0”

4.5 Energy Recovery – see HVAC division 23

4.6 Standby Power

Electrical failure:

MIT enjoys a very reliable electrical system. Loss of normal power is not frequent. However, there may well be situations where back up or emergency power is needed. This is generally only warranted in the case of unusually high hazards. In some cases, it may be impractical to provide emergency power to run fans at their normal capacity and a reduced capacity may be considered.

The most common source of backup power at MIT are diesel generators. The following items should be considered:

1. Support systems to generator like fuel pump must also be connected to emergency or back up power.

2. Reciprocating engines connected to generator usually take approx. 10 second or less.

3. The amount of fuel storage should be carefully evaluated to ensure it meets the required backup time.

4. Natural Gas operated systems can also be considered.

System Priority in the event of a power failure:

1. When possible running laboratory exhaust systems at reduced capacity is preferred. Areas of greatest risk will need to be prioritized to ensure lab personnel safety during the power enforced suspension of building operations. Within laboratories, priority should be given to maintaining containment at the fume hoods. Additional priority should also be placed on the maintenance of containment within hazardous gas, solvent, and chemical storage systems. Depending on the number of fume hoods and containment systems utilized in the laboratory, general lab exhaust can be used supplement/ maintain the negative pressurization of the laboratory.

2. Gas monitoring systems should be on standby power.

3. Independent equipment containment sources such as Biosafety Cabinets (BSC's) and equipment with hazardous exhaust flow (as defined by EHS) will require standby power to maintain containment of any hazard sources, in the event of a power failure. In the case of certain equipment like BSC's (with or without thimble connection), a supplemental UPS to maintain power throughout the standby power switchover may be required. When performing the risk analysis as to whether to provide standby power to any one piece of equipment, MIT advises that the design team also verify the risk of contamination to the research.

4. Extremely valuable research storage devices should be considered as candidates for standby power, and possibly UPS back-up, as warranted. (Examples: Freezers)

5. MIT FUME HOOD REQUIREMENTS

5.1 High Performance Fume Hoods

1. To decrease energy use in laboratories on the MIT campus, EHS recommends high performance fume hoods be considered for installation in new and renovated laboratories.
2. The general design and construction of laboratory chemical hoods should conform to applicable guidelines (see current editions of the ACGIH Industrial Ventilation: A Manual of Recommended Practices, ANSI Z9.5 Laboratory Ventilation standard and SEFA Recommended Practices for Laboratory Fume Hoods).
3. High performance hoods have design features such as improved aerodynamic airfoils and greater depth that optimize contaminant capture efficiency at lower face velocities than the traditional fume hoods models from the same manufacturers and therefore require less airflow.
4. For most applications, high performance hoods are preferred. In limited instances, a higher hood exhaust volume could be required for dilution and this may limit energy savings, but using a high performance hood will allow for future flexibility. Note that for some applications, e.g., acid digestions, operating a fume hood at a reduced face velocity may not be appropriate.
5. Approved Manufacturers/Models (As of December 2015). The following high performance hoods are recommended by EHS. The use of any other hood must be approved by EHS:

a. Kewaunee/Supreme Air LV.
b. Labconco/ Protector XStream.
c. Mott/ Safeguard.
d. Mott/ RFV-2.
e. Note the Hamilton Concept hood is also an approved high performance hood; however, as of spring 2015 Hamilton no longer manufactures fume hoods. Existing Hamilton Concept hoods may be repurposed as approved high performance fume hoods.

5.2 Floor-Mounted Fume Hoods

1. The construction of floor-mounted fume hoods should be in accordance with ANSI Z9.5-latest version.
2. Floor-mounted type fume hoods are generally not recommended as they consume significantly more energy than a standard bench-mounted hood. These hoods are designed for use when a standard hood is inadequate to contain larger equipment. They are generally intended to be used with the lower doors in place during normal operations since opening the lower door can result in a loss of containment.
3. Modifications to the hood maybe necessary if the lower doors are required to opened during the normal course of work.
4. The face velocity of the hood should be 100 fpm with the lower doors in place and the upper doors at 18 inches.
5. EHS should be contacted to evaluate all designs involving the installation of floor-mounted hoods.

5.3 Laminar Flow Fume Hoods

1. Laminar flow exhausted hoods are designed to provide protection to the researcher and also provide a clean environment within the hood for the research material.
2. Like walk-in hoods, laminar flow hoods consume significantly more energy than standard fume hood and should be installed only when absolutely necessary. Air enters through the sash opening and is immediately drawn through a grill in the front before it comes into contact with the research sample. At the same time, room air is drawn through a HEPA filter at the top of the hood which blows down over the research sample. The proportion of room air entering the sash and room air entering through the HEPA filter is critical and should be set by the manufacturer.
3. EHS should be contacted to evaluate all designs involving the installation of laminar flow hoods.

5.4 Perchloric Acid Fume Hoods

1. The use of heated perchloric acid requires a special hood designed specifically for it. The hood should be on its own separate fan and not manifolded or joined to other non-perchloric acid exhaust systems.
2. The hood should be designed with a wash-down system for the hood and associated duct

work. Fans should be induction type so that no moving parts are exposed to perchloric acid vapors. The hood surfaces and ductwork must be constructed of materials that will not react with perchloric acid.

3. There are additional requirements for perchloric acid hood installations. See the current edition of Industrial Ventilation: A Manual of Recommended Practice for Design and ANSI/AIHA Z9.5 Laboratory Ventilation for more information.
4. Perchloric acid hoods should meet the same containment performance as the MIT standard chemical fume hoods. In addition, they should be constructed of stainless steel and have welded seams throughout. No taped seams, joints, putties, or sealers can be used in the fabrication of the entire hood duct system. The perchloric acid hood also requires an internal water-wash system to eliminate the buildup of perchlorates. The water wash system should consist of a water spray head located in the rear discharge plenum of the hood, plus as many more heads as are required to ensure a complete wash down of all internal surfaces of the ductwork. This includes the run from the work surface fan to the discharge stack on the roof. To facilitate satisfactory water drainage of the ducts internal surfaces the route from the fume hood to the exhaust fan should be vertical, with no horizontal runs.
5. Perchloric acid hoods often represent a significant financial investment and there may be additional options for using this material. EHS should be contacted to evaluate all designs that involve its use.

5.5 Special Note on Hoods Used for Acids

1. Depending on the quantity and process, the use of some concentrated mineral acids can cause corrosion and deterioration of hood surfaces, ductwork, control valves, and fans (this is particularly notable in the case of aqua-regia and especially boiling aqua-regia).
2. In some cases, the use of hoods with Teflon coated metal parts and acid resistant ductwork may be appropriate.
3. In more extreme cases hoods designed with built in scrubbers may be appropriate. These hoods generally use a water mist to dissolve the acid vapor. The mist is then collected and either neutralized at the hood or using the building neutralization system.
4. It should also be noted that hydrofluoric acid (HF) can damage glass hood sashes. Some manufacturers offer sash material that is resistant to HF.
5. EHS should be contacted to evaluate all fume hood designs that involve the use of acids.

5.6 Additional EHS Requirements

1. Design sash height at 18 inch unless researcher and EHS agree on another height.
2. Sash stop required if operating height less than full open.
3. Tissue screen for bottom slot is required.
4. All fume hoods are required to have audible and visual alarms that are capable of indicating when the fume hood flow rate drops below 20% of the design criteria. In Variable Air Volume hoods the manufacturer of the VAV valve should supply a corresponding controller with a digital readout of face velocity and alarm. For Constant

Air Volume Hoods an airflow monitor with digital readout of face velocity such as the TEL AFA 1000 or MIT approved equivalent is required.

5. Exhaust and supply control devices need to be of laboratory grade for appropriate response times for laboratory hoods or SLEV.
6. No cup sinks unless allowed by EHS.
7. Consider combination sashes for 6 foot or greater hoods, vertical sashes only for 4 and 5 foot hoods
8. No natural gas unless allowed by EHS.
9. Fume hoods and ducts made of combustible material (i.e., plastic) must have flame spread rating < 25, smoke index < 50 and meet Factory Mutual test protocol 4910.
10. Sash operating mechanism should be chain drive (versus cable).
11. Valves specified for hoods should be "front-loaded" (versus rod-driven). Front loaded valves allow for replacement/service of the valve without having to access through panel inside the hood.

5.7 Face Velocity Criteria

1. The MIT face velocity criteria for the traditional fume hoods still in use on most of the MIT campus remains an average of 100 feet per minute (fpm) with an acceptable range of 90 to 110 fpm.
2. For high performance fume hoods EHS recommends an average design face velocity of 80 fpm at the maximum design opening. A tighter tolerance for average face velocity is required for high performance hoods.
3. The measured average face velocity of high performance hoods shall not be less than 75 fpm. An exception to these criteria is the Mott RFV-2 hood which can be operated at 70 fpm at the maximum design opening. The measured average face velocity for this hood shall not be less than 65 fpm.

5.8 Additional Energy Conservation Features for Fume Hoods

1. Variable Air Volume (VAV) systems should be considered for all laboratories, including those with high performance hoods, where their use could result in reduced energy consumption.
2. Other energy conservation measures related to fume hoods such as proximity sensors and automatic sash closure devices require approval by EHS.

5.9 Fume Hood and BSC (ref 6.3) Placement Criteria

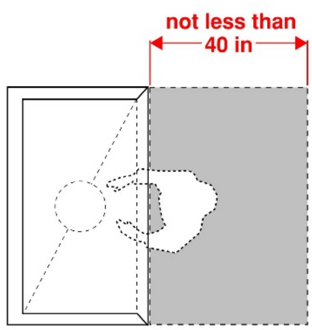
The location of fume hoods within laboratories is critical to hood performance and safety of the occupants. In general, the far end of the lab away from supply air diffusers and low traffic areas are best. Specifically:

1. Hoods should be located away from laboratory exits so the occupants do not have to pass in front of the hood to evacuate the lab.

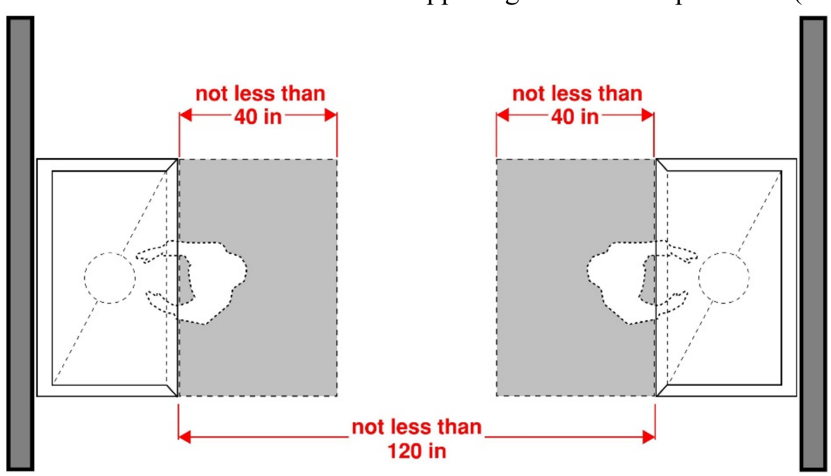
2. The location of supply air diffusers should also be taken into consideration. Diffusers that emit supply air with a significant directional component and velocity in front of the hood can have a serious effect on hood performance. Ideally laboratory diffusers should be large with a significant number of perforations to allow for the gentle introduction of air into the lab. The recommendations outlined in ANSI/AIHA Z9.5 Laboratory Ventilation should be followed; specifically, 5.3.2 Supply Air Distribution.
3. Partially enclosed alcove locations should be avoided as they may affect hood performance.

Due to the possibility that disturbances in the air adjacent to a fume hood can lead to a loss of containment, the following fume hood placement guidelines are recommended. The dimensions listed in items 1-10 do correspond (where dimensioned) to the NIH DRM Appendix I guidelines.

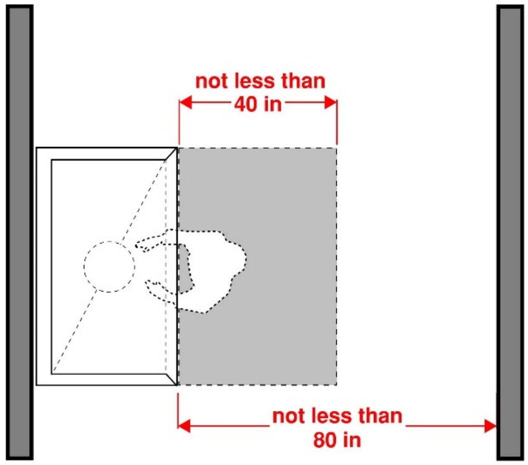
1. Maintain an undisturbed 40" clearance zone in front of the fume hood.



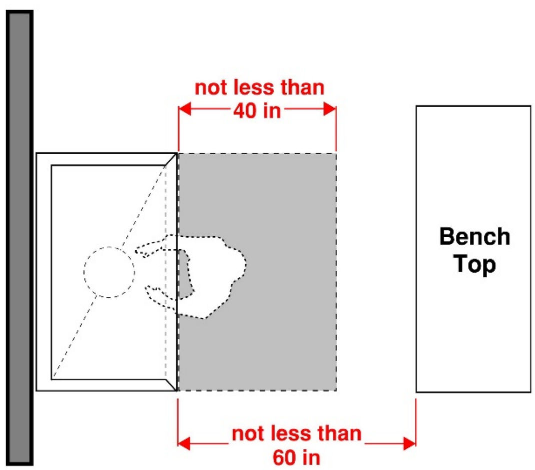
2. Maintain a distance of 120" between opposing fume hood open faces (180°).



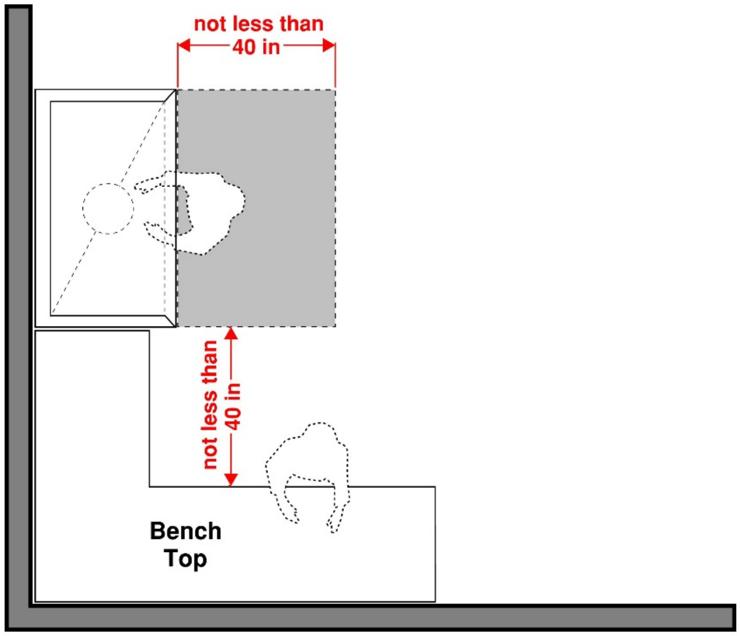
3. Maintain 80" clear from the face of the fume hood to opposing wall surfaces.



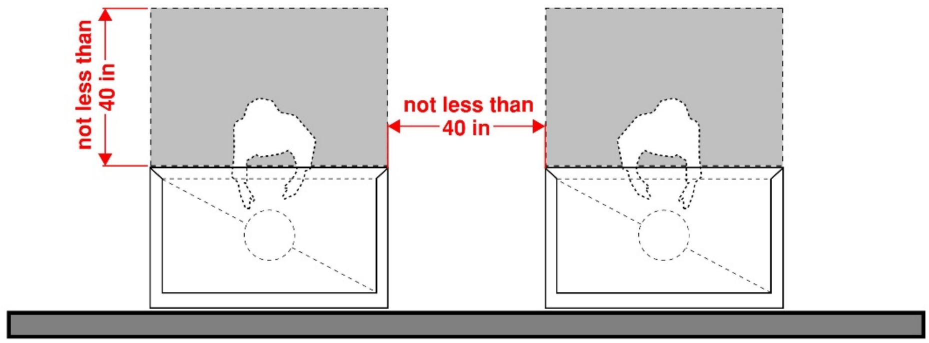
4. Maintain 60” clear from the face of the fume hood to opposing bench tops with occasional traffic.



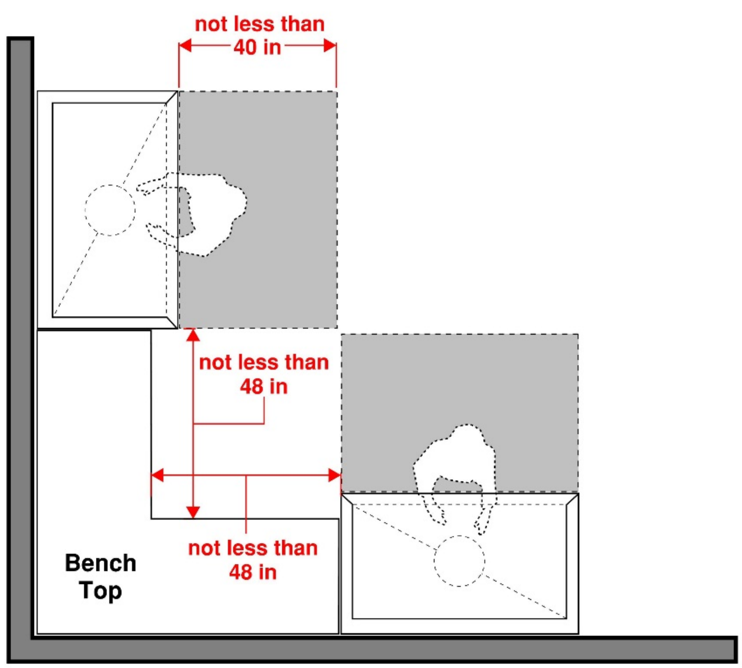
5. Maintain 40” clear from the side of a fume hood and a perpendicular (90°) bench top to avoid placing Fume Hoods inside adjacent lab bench work areas, in which the work zone of the fume hood and lab bench overlap.


not less than
40 in
not less than
40 in
Bench
Top

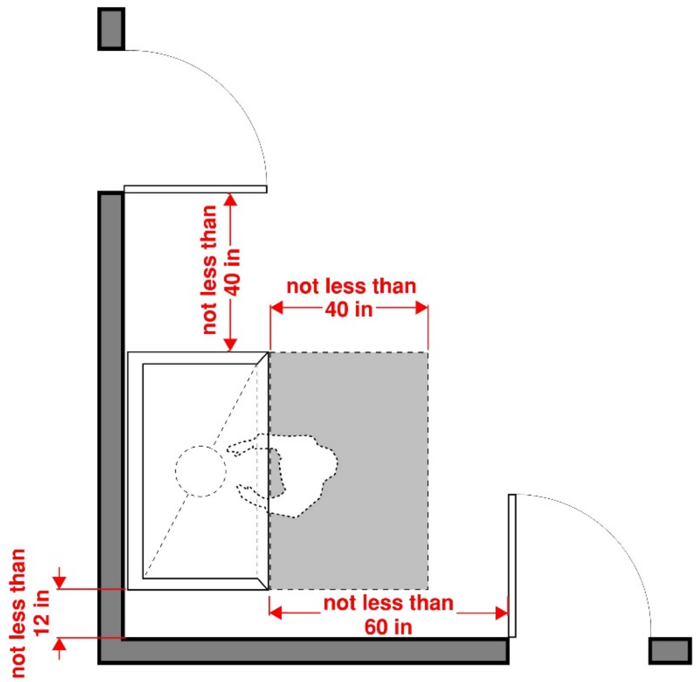
6. Maintain 40” clear between adjacent independently engineered fume hoods. (same wall/run).



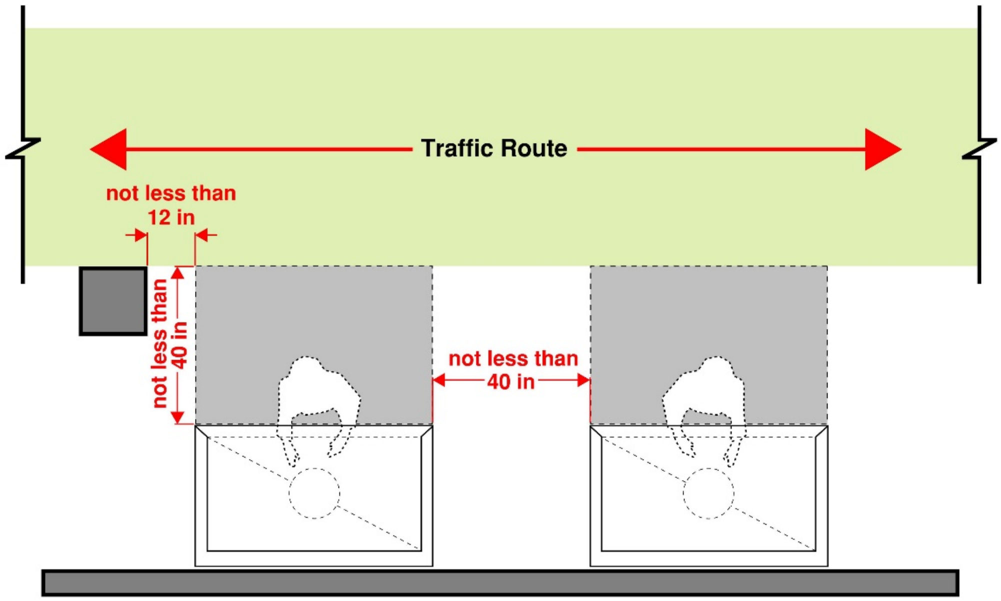
7. Maintain 48” clear to the inside corner when fume hoods are placed on adjacent perpendicular walls (90°).



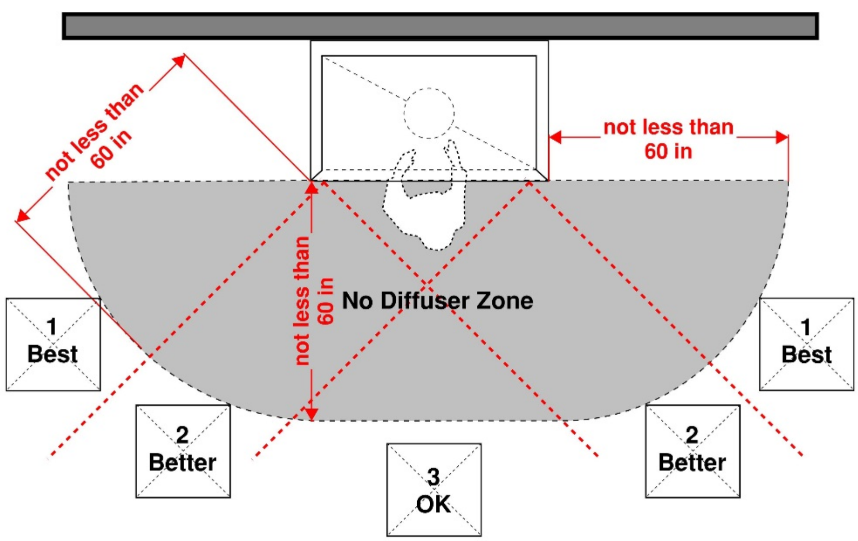
8. Avoid placing fume hoods between adjacent doors if possible. If unavoidable, maintain 60” clear to the door adjacent to the face, and 40” clear to doors adjacent to the side panel.



9. Avoid placing fume hoods in high traffic routes within the laboratory.



10. Supply air distribution systems shall be designed to minimize turbulence and avoid impacts to the containment and performance of Fume Hoods, with exhaust grilles and registers located away from supply air diffusers in a manner that creates a uniform, low velocity airflow across the room. The distance from a fume hood to a diffuser depends on the type of diffuser, throw pattern and terminal velocities that result over the range of temperature and supply volume. Unless otherwise justified through further investigation (CFD or mockup), the minimum distance between a diffuser and the plane of the sash shall be 5 feet.



The spatial relationship of a supply diffuser to the fume hood is critical to optimizing it's performance with zone 1 being the best and zone 3 being adequate, Lab designers should use caution when locating diffusers in Zone 3 in front of a hood opening, as air directed perpendicular to the plane of the sash can be more detrimental to hood performance than cross drafts of similar velocity directed parallel to the opening. If diffusers must be located within this nominal 5'-0"/ 60" 'No Diffuser Zone' or NDZ, CFD may be necessary to evaluate potential problems and modified ASHRAE 110 compliance. In addition, the terminal velocity of the supply air should not exceed ½ of face velocity of the fume hood.

6. BIOSAFETY CABINETS

6.1 Biosafety Cabinets (BCS)

Biological Safety Cabinets (BSCs) can be exhausted into the lab with the exception of BSL-2+ spaces. In very limited circumstances, an assessment of the materials or conditions of use may lead to a need to have a canopy or loose connection to the lab exhaust system. Please contact the EHS Biosafety Program for more details

6.2 BSC Classes

There are three classes of BSC. NSF International Standard 49 details the regulatory requirements for testing and certifying a Class II BSC, the most common type of BSC currently in use. There are different types of Class II BSC, including A1, A2, B1 and B2.

Class II cabinets are suitable for biosafety levels 1, 2, and 3.

The majority of BSC units on campus are Class II Type A1/A2 which produces a clean working environment for product protection as well as personnel and environmental protection via laminar air flow. Air is drawn into the cabinet, circulates via internal blower through a HEPA filter which pushes clean air down onto the working surface. 70 percent of the air is exhausted and 30 percent is re-circulated into the BSC. This produces a protective air curtain which provides containment with in the cabinet.

6.3 BSC Location and Ventilation Requirements

Location of BSC is important due to the fact that the air curtain created by the laminar flow is easily disturbed, which can compromise containment of the materials, as well as introduce environmental contaminants into the working area. **Please refer to Section 5.9 for BSC placement criteria.**

Class II Type B1 cabinets must be hard ducted, and Class II Type B2 cabinets are total exhaust. MIT BSP does not recommend installation of Type B1 or B2 cabinets unless absolutely required.

Class I BSC is a directional air flow unit that offers environmental and personnel protection only. There is no product protection in this model as it functions similar to a chemical fume hood. Since this cabinet does not offer protection of material from contamination their use in research has declined.

6.4 BSC Options

Many manufacturer options are available in purchasing or customization of a BSC. Options include installation with vacuum nozzles, UV lights,(these are discouraged) Sash alarms, and built-in containment for an aspiration flask set-up, etc. For BSCs with energy efficiency monitors, an electrical outlet should be installed at or near the top of the BSC.

The MIT CAB/ESCRO Policy no longer allows Bunsen burners, including the "touch type", or other heat sources while working inside a BSC. Any point-source of heat may disrupt the protective laminar air flow pattern of a BSC. Flammable gas lines shall not be plumbed to BSCs.

6.5 Class II Type A2

Class II Type A2 Biosafety Cabinet (BSC) installations after must comply with requirements for design, construction, and performance contained in NSF/ANSI 49- latest version.

BSCs purchased for MIT laboratories should be NSF/ANSI 49 certified by the manufacturer.

NSF/ANSI 49 includes field performance tests and requirements. If a BSC is to be exhausted, canopy (thimble) ducting is required along with an airflow monitor in the exhaust duct with an audible and visual alarm.

6.6 BSC and Renovations

BSCs are often reused after renovations of existing biological research laboratories. As part of the renovation, BSCs must be brought into compliance with NSF/ANSI 49.

Cabinets should only be retrofitted to a canopy connection with available manufacturer conversion kits or a custom fabricated canopy connection. Note that the exhaust volume for canopy connections is slightly higher and the design of the canopy is critical to the performance.

For older model BSCs that cannot accept a canopy connection, and the research involves the use of volatile reagents in the cabinet, cabinet replacement should be considered. Alternatively, with MIT EHS approval, cabinets may be un-ducted and used as free-standing cabinets.

All cabinets must be NSF/ANSI 49 field recertified prior to and after relocation since during a move it is possible to damage the cabinet and or shift the seating of the cabinet HEPA filters. Recertification ensures the proper functioning of the cabinet in the new location.

7. LAB SAFETY DEVICES

7.1 Emergency Eyewashes and Showers

Please note content also included in Section 2.6 EHS Thematic Folder

Meet or exceed the following standards:

1. ANSI/SEA Z358.1 Standard for Emergency Eyewashes and Shower Equipment.
2. OSHA 29 CFR 1910.151(e) Eyewashes.
3. 248 CMR 10.13(l) Piping and Treatment of Special Hazardous Wastes.

Introduction

Emergency eyewashes and showers are to be installed in all laboratories and other types of non-lab work areas, which have hazards that include but are not limited to those listed below. If the current hazards do not trigger the need for this equipment, piping shall be installed during the current renovation (left capped at either end to avoid "dead legs" and labeled for future use). This is to facilitate installation of eyewashes and/or showers when hazards change (often before the renovation is completed or soon after) or during a future space change. The goal is to reduce the cost of, time involved, and impact of the installation on the users.

Hazards and other triggers:

1. All lab spaces equipped with sinks or fume hoods.
2. Equipped with ventilation equipment chemical fume hoods, specialized local exhaust ventilation (SLEV) and containment equipment such as biological safety cabinets.
3. Use and store chemical and biological materials (aka wet labs). This includes but is not limited to corrosive or flammable liquids. The Cambridge plumbing inspector will require eyewashes and showers in labs regardless of the amount of chemicals
4. Open flame devices are used;
5. Spaces designated as Biosafety level (BL) 1 and higher.
6. Animal quarters (vivarium) designated as Animal Biosafety level (ABL) 1 and higher: Eyewash should be located outside of rooms with animal cages to prevent contamination of the animals' drinking supply. Eyewashes and sinks should be installed in animal procedure rooms including non-human primate testing and test preparation areas.
7. Animal quarters, which have cage washing facilities because 55-gallon drums of corrosive cleaning compounds are used.
8. Corrosive cleaning areas including labware washing, commercial kitchens.
9. Shops with metal and wood-working equipment (particulates are produced)
10. Other non-lab facilities with the above types of exposures including pH neutralization system locations, battery charging areas, spraying operations, high dust areas, printing areas, shops, hazardous waste main accumulation areas, etc.

This covers almost every lab, lab support space, and workshop at MIT. Coordinate location of emergency eyewashes and showers with fume hoods and with drains, to minimize the potential for spills from fume hoods entering drains.

Equipment Specification

1. The lever that is pushed, pulled or squeezed to activate the eyewash/ shower should be designed to remain on without requiring the use of the operator's hands. It should be easy to operate in an emergency.
2. The water or fluid should flow until intentionally shut off or until the specified amount has been discharged.

Eyewash

1. Fluid should be provided to both eyes simultaneously via two nozzles or other means.
2. Nozzle protection should automatically come off when the water/ fluid starts to flow.
3. Eyewashes must be located where they can be effectively used hands free by all researchers, once the unit is engaged. Provide accessible clearances and heights for users with disabilities.
4. There are access limitations with some sink-mounted eyewashes for individuals who might need them at a lower height due to disability or short stature. Lower eyewash stations may be required in areas where needs have been identified.
5. MIT researchers prefer eyewashes that are activated by pulling one vertical arm downward. These have a much smaller footprint compared to the swing activated (horizontal) type, which spray water on the bench during testing.
6. The endpoint of the eyewash arm shall be 14 inches or less from the leading edge of the lab bench. Users of all heights must be able to lean over the sink to reach the water stream. Install longer arm eyewashes if necessary. If the PI agrees, units may be panel mounted (at a 45-degree angle outward).
7. Eyewash units should be installed at sinks for proper draining to allow for required weekly testing of the units. If there isn't a sink in the room and a sink can't be installed, then appropriate provisions must be made in the plumbing design to allow for capture and drainage of one minute's flow of water from the unit to allow for the required testing. (cup sinks are not adequate due to insufficient flow capacity)
8. Eyewashes should not be installed in the wall unless the unit is connected to the lab waste system and the wall is protected from water damage/ mold growth.
9. Do not install new drench-hose type eyewashes in new labs or during renovations or repairs as primary, fixed-eyewash stations. Hose-types can only be installed as supplementary equipment and cannot serve as approved eyewashes, per the State Plumbing Board and for accessibility limitations. If the lab only has room for one eyewash, then only install the approved type of eyewash.
10. Where the tempered water supply exceeds 45 psig, provide pressure reducing valve(s) to control delivery pressure to 45 psig static and not less than 30 psig during unit activation.
11. Faucet-mounted eyewashes are prohibited.

Shower

DOF has a new requirement to connect a water flow sensor to the BMS. (VERIFY w/ DOF)

The end of the long handle should hang as close to the wall and as far away from the path of travel as possible. This is to prevent inadvertent activation and to prevent head injuries. Acceptable Options: A handle that is wall mounted. A handle that can be adjusted in length based on the needs of the current lab users. A long chain with eye hooks so the chain hangs along the wall. A handle that is behind the smaller panel of a double leaf door.

Some of the specifications for the water or fluid supply are described below.

ANSI Z358.1-2009 527 CMR 10.02 248 CMR 10.13	**Eyewash**	**Emergency Shower**
Water/Fluid temperature	*Tepid water (ANSI does not specify temperature range)* *Tempered water between 70 and 90 F (527 CMR 10.02, 248 CMR 10.13)*	
water/fluid pressure	**Plumbed or self-contained Eyewash:** *not less than 0.4 gpm for 15 minutes* **Velocity** *should be low enough to be no injurious to the user* If the central tempered water system has a booster pump to ensure a pressure of 30 to 35 psig is achieved while running an emergency shower at the top floor, then the plumbing contractor must control the pressure at floors where static pressure exceeds 45 psig. The eyewashes should be limited to not more than 45 psi static and 30 psig minimum when activated.	*Minimum of 20 gpm at a velocity low enough to be non injurious to the user (ANSI Z358.1)*
water/fluid quality	*potable water, preserved water, saline solution or any medically acceptable solution* (ANSI) potable water (527 CMR 10.02, 248 CMR 10.13)*	
Control valve	*valve should be the on/off type designed to remain activated until intentionally shut off*	
Prevent stagnation	*installing equipment in a manner that prevents the stagnation of water in the piping 248 CMR 10 section (l) 5*	

Location selection and installation standards

Select location that is adjacent to the hazard but there must be enough room so that the victim and emergency responders will be safe. (For example, installing an eyewash/ shower "immediately adjacent" to an exhaust hood is not recommended.) The emergency shower and eyewash unit must be located on the same level of the hazard and the path of travel must be free of obstructions that would inhibit the immediate use of the equipment. Doors to the eyewash or shower must swing in that direction. For strong acid and strong caustic hazards the eyewash unit should be immediately adjacent to the hazard.

The ANSI standard for Emergency Eyewash and Shower Equipment specifies the distance of the unit from the standing surface and the wall (or the nearest obstruction). This is to ensure that the unit will be reachable by any user and that the user will not be injured.

Emergency showers should be located within the laboratory as close to the main door as possible. This minimizes water possibly being sprayed on to electrical equipment that may be in the lab and it is less likely that items will block access to the shower. Do not wedge shower between the wall and the door when it is in the open position.

36 inch clearance zone for showers:

No obstructions, protrusions, or sharp objects shall be located within 16 inches from the center of the spray pattern of the emergency shower. Electrical apparatus, telephones, thermostats or power outlets should not be located within 18 inches of either side of the emergency shower or eyewash.

If the equipment is installed outside the lab, then the lab door must swing out and the doorway must be recessed so pedestrians will not be hit by the door. Most lab doors swing into the lab to comply with the Building Code. The emergency shower and eyewash unit must be located on the same level of the hazard and the path of travel must be free of obstructions* that would inhibit the immediate use of the equipment. *The Cambridge Plumbing Inspector will not issue a permit to install an eyewash or a shower if the door that does not swing in the direction of the path of travel because he considers this to be an obstruction.

<table>
<tr><th></th><th>Eyewash</th><th>Emergency Shower</th></tr>
<tr><td>OSHA
29CFR 1910.151(c)</td><td colspan="2">*Within the work area for immediate emergency use.*</td></tr>
<tr><td rowspan="2">ANSI
Z358.1-1998
7.7.4 and 4.6.1</td><td colspan="2">*In accessible locations that require no more than 10 seconds to reach (...), on the same level as hazard* (i.e. on the same floor). *The path of travel (to the safety equipment) should be free of obstructions* (i.e. <u>locked</u> doors, boxes, etc.). It is acceptable to go through an unlocked door.</td></tr>
<tr><td colspan="2">*For a strong acid or caustic, (it) should be immediately adjacent to the hazard.*</td></tr>
<tr><td>527 CMR
10.02 (2)
248 CMR
10.13</td><td colspan="2">*Should not be located greater than 50’from an experimental area*</td></tr>
</table>

Accessibility and Signage

Emergency wash equipment that meets the ADA requirements should be installed when new buildings are constructed or when the building is renovated. Designers of new labs should refer to the Massachusetts Access Architectural Board (MAAB) guidelines for approach and reach.

Typical Solution: One sink is at the regular height and the eyewash is installed there. One shallow sink is at the lower height required by ADA with nothing underneath it. The sink is equipped with a tight fitting cover so the lab bench can be used until it is needed. Alternatively, install the piping in such a way that the lower sink could be installed quickly when the person, who actually needs it, starts working.

Each emergency shower or Eyewash location "should be identified with a highly visible sign and the area around the equipment should be well lighted". (according to ANSI Z358.1). The signs must have contrasting color of green and white and be at least 70 square inches in area (527 CMR 10.02 (2)). Refer also to the Signage Thematic Folder in the MIT Design Standards.

The wall sign that comes with the equipment shall be visible from most points within the lab or work area.

The area under the shower shall be clearly identified to ensure that the lab users do not block access to the shower by using a "keep area clear" slip resistant graphic demarcation on the floor. This graphic should be permanent and resistant to wear. Refer also to the Signage Thematic Folder in the MIT Design Standards.

7.2 TGM/ Gas & Liquid Vapor Detection

Please note content also included in Section 19 EHS Thematic Folder

Meet or exceed the following standards:

1. Massachusetts State Building Code, 780 CMR, most current edition
2. Massachusetts Comprehensive Fire Safety Code, 527 CMR 1.00, 2015
3. International Fire Code, 2009
4. Factory Mutual Global Data Sheets, 2015
5. Standard on Fire Protection for Laboratories Using Chemicals, NFPA 45, 2015
6. Compressed Gases and Cryogenic Fluids Code, NFPA 55, 2016
7. Compressed Gas Association Standards
8. Standard System for the Identification of the Hazards of Materials for Emergency Response, NFPA 704, 2012
9. SEMI International Standards
10. MIT Gas and Vapor Monitoring SOP

Introduction

Gas monitoring may be required when highly toxic, toxic, flammable, or pyrophoric (spontaneously combustible in air) gas use is planned. Under some conditions, oxygen monitoring is required in locations with compressed and liquefied inert gases and LEL (Lower Explosive Limit) monitoring in locations such as storage areas for flammable gases and chemicals. This section applies to Lab and Non-Lab areas.

General recommendations for permanently installed gas monitoring systems:

1. Monitor type, alarm set points, automated actions and notifications for monitoring systems are determined by the project design review team based on MIT EHS and Facilities specifications, code requirements, building infrastructure and research needs
2. All monitoring systems must report alarm details back to a continuously monitored station (e.g. the Facilities Operations Center and if available, a department response team.).
3. A visual and audible alarm must be present inside and outside of the lab with the ability by emergency responders to silence the alarm. Alarm details in a display panel (alarm type, level, etc.) must be available inside and immediately outside of the monitored area
4. A remote monitor is required in the Fire Command Room or near the main building Fire Alarm Panel. Signage should indicate the warning signal intent. The signage shall include appropriate hazard warnings, as well as response instructions (e.g., “Do Not enter the laboratory if the alarm has been activated”) contact information and emergency phone numbers. The researcher is responsible for writing a response procedure that is reviewed by EHS which they are posted at the lab including alarm levels and contact information that the DLC, Operations Center and EHS would follow in case of an alarm. The response protocol would be distributed to Operations Center, EHS and be covered as part of the lab specific training. The response procedures and any other supporting documentation will be kept in a secure location such as in the Fire Command Room or blue locked box mounted outside the lab entry
5. The location of gas sensors will be based on the properties of the gas and potential leak points. Sensors shall be located within 12 inches of the floor for gases heavier than air and near the ceiling for gases lighter than air. Ambient air sensors for toxic gas monitoring will be located near breathing zone height
6. Monitoring equipment make/models should be standardized as much as possible to facilitate maintenance requirements. Contact Facilities and EHS to ensure that an acceptable monitor is purchased
7. Emergency power, battery backup (24 hours) must be provided for monitoring systems. The monitoring system should continue to operate without interruption

Pyrophoric, Highly Toxic and Toxic Gases

Certain gases with very high toxicity and/or pyrophoric properties (e.g., silane, arsine, and phosphine) require continuous 24 hour air monitoring in the work area and ventilated equipment/enclosures and possibly duck work. Automatic gas shutdown at the gas source and tool shutdown in the event of ventilation failure or gas detection may also be required. An automatic fire detection system must be installed in rooms or areas where highly toxic compressed gases are stored or used. Flame detection is required for pyrophoric gases.

Toxic gas alarm set points are based on the American Conference of Industrial Hygienist Threshold Limit Values (ACGIH TLVs). Typically monitors are set to alarm at half of the TLV and the TLV. For detection inside of ventilated enclosures (e.g., gas cabinet or tool enclosure) the lab should be evacuated and gas source automatically shut down. For highly toxic and pyrophoric gas detection at the TLV level or higher in ambient/breathing air, the building is evacuated.

The monitoring system shall be equipped with an audible and visual alarm indicator. The audible signal shall be at least 15 dB above the ambient sound level. The visual alarm beacons shall be amber for equipment and gas cabinet/enclosure alarms and blue for ambient alarms. The visual alarm beacons shall be labeled.

While toxic gas use may not require the same monitoring and controls as very toxic gases, each planned use of toxic gas requires some level of engineering controls and/or monitoring. Especially of concern are toxic gases that may not provide adequate warning below the TLV due to high or no odor thresholds and olfactory fatigue (e.g., carbon monoxide, hydrogen sulfide or hydrogen chloride).

Highly toxic, toxic and pyrophoric gas monitoring requires that sensing ports be located in the gas cabinet, tool/equipment enclosure, and lab area.

Compressed gas cylinders containing highly toxic, toxic and pyrophoric gases are required to be stored in gas rooms or approved cabinets, exhausted gas cabinets or exhausted enclosures (Refer to section 3.1 for code requirements).

The cabinet shall be equipped with an excess flow control valve and flow restrictor in cylinder and exhaust monitor/interlock for gas flow shutdown upon exhaust loss.

There should be a manual emergency shutoff at the gas cabinet.

For high hazard group H occupancies, the exhaust ventilation system serving gas cabinets, as well as any tool enclosures, shall be provided with emergency power.

The local authority having jurisdiction may require additional safeguards.

1. Note: SEMI and Massachusetts Building Code define a highly toxic gas as having an LC_{50} of 200 ppm or less and a toxic gas as having an LC_{50} of greater than 200 ppm and less than or equal to 2000 ppm for a one hour exposure to albino rats between 200 and 300 grams. [SEMI F6-92]. NFPA 704 uses an LC_{50} of less than or equal to 1000 ppm for its highest health hazard rating of 4 and an LC_{50} of 1000 to 3000 ppm for a hazard level of 3

Small returnable cylinders (lecture bottles) containing less than 10 cubic feet of gas by volume that are kept inside gas cabinets or fume hoods:

1. Require local (temporary) monitoring

2. Must be kept in the gas cabinet/fume hood at all times
3. If their use is restricted to inside the hood and not piped to equipment outside the hood, an excess flow control valve/flow restrictor is not required
4. If their use in not limited to inside the hood and piped to equipment outside the hood the cylinder must be equipped with an excess flow control valve and flow restrictor in cylinder and the equipment and ambient air must have continuous monitoring
5. See Table 1 for suggested sequence of operations

Inert Gases

Some research laboratories use compressed and liquefied gases in locations where the potential for a low oxygen, <19.5% O2, atmosphere exists. These areas are required to have oxygen sensors. Examples include liquid helium cooled magnets or dilution refrigerators, MRI rooms, MEG rooms, nitrogen generator rooms, nitrogen filling stations and storage areas for inert gases. Where there is potential for high level oxygen, the set point would be 23.5%.

EHS with assistance from the project design group will review the proposed research, location and gas quantities to determine whether oxygen level monitoring may be required. In some cases provisions for emergency exhaust triggered by an alarm may be required. Positioning of sensors should be based on gas density at the time of release relative to ambient conditions. Sensors for MRI and MEG rooms should be designed for these rooms to eliminate interference with the image quality.

The signage shall include appropriate hazard warnings, as well as response instructions (e.g., "Warning! Low Oxygen Alarm") contact information and emergency phone numbers. Refer to a template sign for consistency. Response protocols should also be developed and distributed as outlined above in the toxic gas section.

See Table 1 for suggested sequence of operations.

Flammable Gases

The purpose of the lower explosive limit (LEL) monitoring of gases within a laboratory space or gas storage room is to give early warning to personnel of a potentially hazardous condition.

When a gas is both toxic and flammable or pyrophoric, the more stringent (sensitive) monitoring requirement shall be used. Both monitors are not required.

The monitoring system shall be equipped with an audible and visual alarm indicator. The audible signal shall be at least 15 dB above the ambient sound level. The visual alarm beacons shall be labeled.

The location of gas sensors shall be determined based on the properties of the gas.

Compressed gas cylinders containing flammable gases shall be stored be in a location equipped with a fire suppression system. This shall be a room, a gas cabinet, or other code-approved enclosure.

Flammable gas cabinets do not require fire suppression systems, if the room that they are located in is protected by a fire suppression system.

Any flammable gas cylinder containing greater than 33 cubic feet of gas must be contained in a gas cabinet, if sprinkler protection is not provided in the lab.

The cabinet shall be equipped with an excess flow valve and exhaust monitor/interlock for gas flow shutdown upon exhaust loss.

There should be a manual emergency shutoff at the gas cabinet.

For high hazard group H occupancies, the exhaust ventilation system serving gas cabinets, as well as any tool enclosures, shall be provided with emergency power.

Flammable gases should be monitored by a continuous monitor in the lab room and any non-toxic flammable gas cylinders outside a gas cabinet should have an excess flow valve. For non-toxic flammable gas, sensors are required in the gas cabinet, equipment/tool enclosure and lab area.

Exceptions:

1. When the cylinder contains less than or equal to 10 cubic feet of non-toxic flammable gas by volume (lecture bottle)
2. Natural gas plumbed as a "house gas" to labs need not be monitored
3. For experiments using a small cylinder of flammable gas (Airgas size 35, approximately 33 cubic feet of gas)
4. If ventilation in the space is adequate and the release risk is not higher than normal, continuous monitoring may not be required but is still a best practice
5. If monitoring is used, hand-held or local alarm is acceptable
6. When gas is flowing, the experiment should be continuously attended
7. All other flammable gas controls apply: flashback arrestor, adequate piping/tubing, restricted flow orifice, excess flow valves

The local authority having jurisdiction may require additional safeguards. Response protocols should also be developed and distributed as outlined above in the toxic gas section.

See Table 1 for suggested sequence of operations.

Flammable Liquid Vapors

The purpose of the lower explosive limit (LEL) monitoring of flammable liquid vapors within a laboratory space or flammable liquid storage room (FLSR) is to give early warning to personnel of a potentially hazardous condition. In the case of an FLSR, these areas are normally unoccupied; thus, it is possible that a leak or spill could result in high concentrations of flammable vapors that could go undetected.

LEL monitoring may be required in locations designed as flammable liquid storage rooms (FLSR) where dispensing will occur. Requirements include:

1. The LEL alarm system shall activate on a single alarm point set at 20 %. This set-point may need to be lower for liquids that are also toxic
2. The monitoring systems shall be equipped with an audible and visual alarm indicator. The alarm signal shall be transmitted to a constantly attended station. The audible alarm shall exceed background ambient levels by 15db. The visual alarm shall be labeled
3. The alarm sensors shall be located no higher than 12 inches above the floor
4. Signage shall be posted outside the FLSR. The signage shall include appropriate hazard warnings, as well as response instructions (e.g. “Do Not Enter if the Alarm has been Activated”) contact information and emergency phone numbers
5. When the flammable liquid dispensing involves use of an automatic pumping system (as opposed to manual,) the pump shall shut-down upon LEL alarm activation (or line leakage detection) to stop the flow of liquid
6. The local authority having jurisdiction may require additional safeguards
7. Exception: FLSR where dispensing will not be conducted

Response protocols should also be developed and distributed as outlined above in the toxic gas section. See Table 1 for suggested sequence of operations.

Toxic and Flammable Gases in Non-Lab Areas

Carbon monoxide monitoring is required in all residential areas, commercial kitchens, Ice Rink and garages (to start ventilation fans only). Natural gas monitoring is required in commercial kitchens. Where there is an assumed high hazard to occupants from the natural gas/carbon monoxide exposure in other non-lab buildings, a discussion will take place between the designers and EHS to determine the appropriate monitoring in these areas. Response protocols should also be developed and distributed as outlined above in the toxic gas section.

Table 1 Suggested Sequence of Operations

Condition	**Building Management System**	**System Supervisory on Fire Alarm**	**Local Horn / Strobe**	**Gas or Liquid Valve Closure**	**Evacuate Lab or Area (local alarm)**	**Evacuate Building/ Alarm Signal to Fire Alarm, Priority 2 Alarm Broadcast to Building Evacuation[5]**

Condition	Building Management System	System Supervisory on Fire Alarm	Local Horn / Strobe	Gas or Liquid Valve Closure	Evacuate Lab or Area (local alarm)	Evacuate Building/ Alarm Signal to Fire Alarm, Priority 2 Alarm Broadcast to Building Evacuation[5]
Highly Toxic and Pyrophoric Gas, ½ TLV in gas cabinet/enclosure and equipment	X		X[1]			
Highly Toxic and Pyrophoric Gas, TLV in gas cabinet/enclosure and equipment	X	X	X	X	X	
Highly Toxic and Pyrophoric Gas, ½ TLV in ambient air	X	X	X[1]	X	X	
Highly Toxic and Pyrophoric Gas, TLV or greater in ambient air	X		X	X	X	X
Toxic Gas, ½ TLV in gas cabinet/enclosure and equipment	X		X[1]			
Toxic Gas, TLV in gas cabinet/enclosure and equipment	X	X	X	X	X	
Toxic Gas, ½ TLV in ambient air Note: carbon monoxide gas in cylinders, 15ppm[3]	X	X	X[1]	X	X	
Toxic Gas, TLV or greater in ambient air Note: carbon monoxide gas in cylinders, 25ppm3	X		X	X	X	X
Flammable Gas, 10% LEL3	X		X[1]			
Flammable Gas, 20% LEL3	X	X	X	X	X	
Flammable Gas, 50% LEL3	X		X	X	X	X
Oxygen, 19.5%	X	X	X	X (for s source)	X	
Flammable Liquid Vapor, 20% LEL 4	X	X	X	X	X	
Flammable Liquid Vapor, 50% LEL 4	X		X	X	X	X

Condition	Building Management System	System Supervisory on Fire Alarm	Local Horn / Strobe	Gas or Liquid Valve Closure	Evacuate Lab or Area (local alarm)	Evacuate Building/ Alarm Signal to Fire Alarm, Priority 2 Alarm Broadcast to Building Evacuation[5]
Flammable Liquid Leak Detection4	X	X	X	X	X	
Emergency Gas Off Pull Station	X		X	X	X	X
Combustion gas carbon monoxide 15 ppm2	X		X[1]			
Combustion gas carbon monoxide 25 ppm2	X	X	X	X	X	
Combustion gas carbon monoxide 200 ppm2 Note: for MIT Ice Rink, set point is 125 ppm.	X		X	X	X	X
Natural gas 10% LEL2	X		X[1]			
Natural gas 20% LEL2	X	X	X	X	X	
Natural gas 50% LEL2	X		X	X	X	X
Panel Trouble	X		X			
Battery Alarm / Power	X		X			

[1] Strobe only
[2] Non-lab areas, residential areas (where required), e.g., residential, boilers, furnaces, water heaters, kitchens, garages, generators, engines
[3] High pressure gas from cylinders in equipment and ambient air
[4] Room/enclosure, equipment and ambient air, lab and non-lab
[5] Pretone, message, alert tone same as fire alarm. Release fire doors

7.3 Floor Drains (Cross Reference EHS Section 2.11)

General

In accordance with Massachusetts Department of Environmental Protection (DEP) regulations, floor drains cannot discharge directly underground or to surface water. Non-approved connections to floor drain systems shall be prohibited.

Per 360 CMR 10.023, the following items are specifically prohibited from discharge to the MWRA sewer system via the floor drain system:

1. Groundwater, storm water, surface water, roof or surface runoff, tidewater, or subsurface drainage, except construction site dewatering in a combined sewer area when permitted by the authority and municipality.
2. Non-contact cooling water, non-contact industrial process water, uncontaminated contact

cooling water, and uncontaminated industrial process water.

3. Fuel oil, crude oil, lubricating oil, or any other oil or grease of hydrocarbon or petroleum origin unless an approved and appropriate gas/oil separator that is in compliance with 360 CMR 10.016 is used.
4. Any liquid, solid, or gas, including, but not limited to, gasoline, kerosene, naphtha, benzene, toluene, xylene, ethers, alcohols, ketones, aldehydes, peroxides and methyl ethyl ketone, which by reason of its nature or quantity or by interaction with other substances, may create a fire or explosion hazard.
5. Any noxious or malodorous liquid, gas, or solid or any other pollutant which either singly or by interaction with any other Waste causes or contributes to the creation of a public nuisance, makes it dangerous for personnel or equipment to enter the Sewer for purposes of maintenance, repair, inspection, sampling, or any other similar activity, or which results in the presence of toxic gases, vapors, or fumes within the sewer system in a quantity that may cause acute worker health and safety problems.
6. The Massachusetts Uniform Plumbing Code requires connection of floor drains to grease traps or oil-water separators in food preparation/service areas, motor vehicle storage maintenance areas, or other areas where floor drains and other plumbing fixtures (including floor sinks, automatic dishwashers, pre-rinse sinks
7. Per 248 CMR 10.00, Uniform State Plumbing Code, floor drains located in areas where motor vehicles are being serviced, or where there is the potential for oil to be spilled must discharge to an oil and gasoline separator.

Research Laboratories

Do not locate floor drains next to laboratory hoods or chemical storage cabinets. Floor drains are not typically part of new laboratory construction or renovation. The decision to install floor drains in a particular research area shall be on a case-by-case basis, such as protecting extremely sensitive and valuable assets on the floors below the area in question due to emergency shower usage (Examples: Clean Rooms, Electron microscope imaging, Etc.) Floor drains from the laboratory should be routed exclusively to the building lab waste/ acid neutralization system. The project team must therefore design their lab waste/ acid neutralization system to account for the maximum additional flow originating from any emergency showers within the catchment area. ANSI Z358.1-2009 states a flow rate at 20 gallons of water per minute for 15 minutes, Section 4.1.2, 4.5.5) The project design team will consult MIT EHS Department if such floor drains are considered. If floor drains are installed for any reasons, they must have provision to prevent off gassing of sewer gas. Trap primers or seals must be installed.

Example:

http://www.rectorseal.com/index.php/sureseal/

Maker Space/ Machine Shop

Ensure that the floor drain shall be equipped with an approved sediment and sand control basket, or the floor drain shall discharge through a sand interceptor. Discharge of multiple floor drains into one sand interceptor is acceptable.

7.4 Autoclaves

Autoclaves should be located in or near biological research laboratories for both treatment of biohazardous solid waste and for sterilization of research materials. Autoclaves come in two basic varieties: gravity displacement and pre-vacuum autoclaves. Both gravity and pre-vacuum autoclaves are acceptable options for MIT laboratories. Autoclaves typically either have a rotary style door handle or hydraulic powered vertical door. Hydraulic-powered vertical doors on autoclaves tend to malfunction more often. BSP recommends the rotary style doors for durability and reliability.

Local exhaust is required to take care of odors as well as heat and moisture. A canopy hood should be fitted above the autoclave and exhausted outside in accordance with NFPA 91. Care should be taken to prevent heat & steam from triggering sprinkler systems. A location for storage of logbooks as well as additional safety equipment, bins, carts, etc. should be available near the autoclave. Autoclaves should be located such that researchers can transport materials to and from the autoclave without passing through high traffic public areas. Special attention should be paid to providing the users with clear and visible system monitoring and notification.

Standard autoclaves are prepared for direct connection to steam lines with a pressure of 50 to 70 psi. Service access should also be considered when setting the unit in place with approximately 24 inches on each side and 18 inches in the back. Complete installation and user instructions are provided by the manufacturer.

References

9.1.2. ASME Boiler and Pressure Vessel Code
105 CMR 480 Minimum requirements for the management of medical or biological waste
NFPA 91: Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids

7.5 Safety Stations

All new laboratory construction is to accommodate a “Safety Station” adjacent to the laboratory entrance/ exit. The intent of a “safety station” is to consolidate all the life safety equipment in an easily understood and recognizable location that can be accessed without drama or difficulty during an emergency situation. The station can include the following items as approved by MIT EHS:

1. Stainless Steel emergency shower/ eyewash combination unit with accommodation of weekly flow testing for the eyewash. If the unit is a wall recessed model, please specify the “daylight drain” model. (Example: recessed Guardian model GBF2372. This type of

unit can also be specified as part of the Guardian "safety center line Model designation GSC*xxxxx* with integral recessed accommodations for all the items listed below)

2. Fire Extinguisher Cabinet.
3. First aid Kit.
4. Spill Kits – based on the types of materials used.
5. PPE (Personal Protective Equipment).
6. In some cases where lab ventilation is being set back in unoccupied times, this space may be a good location for user notification/signage of the lab ventilation status.

In addition, these "Safety Station" locations can be great locations to post hazard signage, laboratory SOPs (Standard Operating Procedure), and other vital information. This communication can be accommodated via either digital, or analog media displays.

7.6 Additional Considerations

Code Requirements

All electrical outlets within 6'-0" of any sink/ water source should be GFI (by code), although certain AHJ's can increase this requirement dependent on use and perceived adjacency of work surfaces.

Emergency gas shut offs – location relative to locked door (discuss future code applicability of IFGC in MA, as well as current NFPA 54 with group)

(IFGC) International Fuel Gas Code. (Where provided with two or more fuel gas outlets, including table-, bench- and hood-mounted outlets, each laboratory space in educational, research, commercial and industrial occupancies shall be provided with a single dedicated shutoff valve through which all such gas outlets shall be supplied. The dedicated shutoff valve shall be readily accessible, located within the laboratory space served, located adjacent to the egress door from the space and shall be identified by approved signage stating "Gas Shutoff".)

The placement of the panel should not enable accidental or malicious de-activation.

Chemical Spill Control

Please provide space for a spill kit as part of the "safety station" in instances of high chemical uses, per the direction of MIT EHS.

Food/ Drink

No food or drink are to be consumed within a designated laboratory environment, as defined by MIT EHS.

It is within the power of the design team to create environments that promote safe behavior by offering viable and attractive alternatives to the smuggling of food and drink into laboratory environments. Bringing food and drink into the laboratory environment not only puts the particular offender at risk of poisoning, but also risks the institution's reputation and liability.

Examples:

1. Placing write-up desks or offices directly adjacent to the laboratory, allowing for direct line-of-sight access, but separating the different hazard levels with a full height glass partition. (This also allows for a more sustainable and energy efficient HVAC solution)
2. Creating collaborative work zones outside of the high hazard laboratory areas, with access to food and drink. These spaces do need to be very conveniently placed to the laboratory area to be effective.
3. Allow for remote observation of equipment within the laboratory from outside (either digitally or through adjacency)

END OF DOCUMENT