Laboratory Design & Construction Guidelines

Department of
Environmental Health & Safety

General Health and Safety

The USC Environmental Health and Safety Department has developed a comprehensive occupational safety and health program to protect the safety and health of all employees. This includes the work setting found in laboratories. Safety and health regulations and guidelines require the use of engineering controls for worker protection, wherever possible, to minimize the potential for occupational exposure to hazards in the workplace. To be most effective, engineering controls for protecting occupational safety and health should be designed into facilities for both new construction and renovated space. This proactive approach can minimize numerous common health and safety concerns in laboratory facilities. Facilities should be designed for ease of maintenance. This is particularly important with regard to the specific containment devices (e.g., HEPA filter housings, HVAC systems, vacuum systems, autoclaves, etc.) designed for the facility.

These health and safety guidelines are to be incorporated, as appropriate, in facility-specific construction documents by the architects and engineers to ensure that health and safety protection is engineered into the design of any new or renovated facility and at the time of construction of the facilities.

While many of the requirements for health and safety engineering are incorporated in these guidelines, it is impossible to cover all possible concerns. The architects or engineers should, whenever possible, consult with USC Environmental Health and Safety personnel for guidance on specific health and safety engineering requirements when designing laboratories for new construction and renovation projects.

Biological Safety

Work performed at the University of South Carolina involves the potential for occupational exposure to biohazardous materials. Biohazardous materials are defined as infectious agents, or materials produced by living organisms that may cause disease in other living organisms. While the laboratory procedures identified as good microbiological techniques are helpful in minimizing potential occupational exposure to biohazardous materials, containment of these agents through the use of good facility design is also extremely important. The intent of this document is to provide architects and engineers with a working knowledge of the facility design parameters required for the construction of facilities, in order to provide for containment of biological hazards.

The CDC and NIH document *Biological Safety in Microbiological and Biomedical Laboratories 5th Edition* provides guidance for the appropriate containment when conducting work involving biological hazards. The four biosafety levels are designated in ascending order by degree of protection provided to personnel and the environment. Special microbiological practices and facility design features serve to enhance worker safety and environmental protection, while also addressing the risk of handling agents requiring increasing levels of containment.

Laboratory Furniture and Equipment

Physical Hazards:

Furniture and cabinets/counters should be designed to be as vertically flush as possible. Kneehole space should be provided for waste containers. Both these approaches allow for better movement in the laboratory and increase safety.

Laboratories that will be used for biological research must be designed for easy cleaning and decontamination. Carpets or rugs are not permitted. Laboratory furniture must be capable of supporting anticipated loads and uses. Spaces between benches, cabinets, and equipment should be accessible for cleaning. Chairs used in laboratory work must be covered with a non-porous material that can be easily cleaned and decontaminated with appropriate disinfectant.

Fire code requires laboratories to maintain an 18 inch ceiling clearance between sprinkler heads and materials stored in the lab. This clearance will ensure that sprinklers are able to adequately disperse water without being blocked by storage materials near the ceiling. All laboratory shelving units should be installed far enough below the ceiling to maintain the required 18 inch ceiling clearance when storing lab supplies.

Casework:

Laboratory casework should be easily cleanable, and finishes should be compatible with materials used for cleaning and disinfection. Fixed casework and countertops should be sealed to walls and floors during installation to minimize harborage of pests and provide a cleanable joint. Countertop materials will vary depending on usage. Traditional materials such as chemical-resistant plastic laminates may be appropriate for some applications. Epoxy resin will apply to most applications where corrosive chemicals are used or where sinks or heavy water usage occurs. Other new materials should be investigated for cost-effectiveness and durability. Stainless steel should be used for glassware wash areas, cold rooms, and other areas as necessary based on usage.

Chemical Fume Hoods:

All containment devices should be located in the laboratory to avoid entrapment, blocking of egress, or safety hazard to the lab occupant. Fume hoods should be located away from areas that produce air currents or turbulence, such as high traffic areas, air supply diffusers, doors, and operable windows. It is also recommended for fume hoods to be labeled to identify the fan or ventilation system where they are connected.

Biological Safety Cabinets (BSCs):

The Class II, Type A2 BSC is the most commonly used cabinet in the USC research labs. This type of BSC provides personnel, product and environmental protection from hazardous particulates such as biological agents that require containment at Biosafety Level 1, 2 or 3. HEPA filtered exhaust air from a Class II, Type A2 BSC can be safely re-circulated back into the laboratory environment if the cabinet is tested and certified at least annually and operated according to manufacturer's recommendations.

BSCs can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or a direct (hard) connection. This would allow for 100% of the filtered exhaust air to be discharged out of the laboratory. Since none of the air is re-circulated, these cabinets may be used for work with biological agents treated with volatile toxic chemicals. Provisions to assure proper safety cabinet performance and air system operation must be verified. The expense for installation and maintenance of a total-exhaust BSC is much higher, and therefore should only be selected and installed when justified based on the specific type of research being conducted in the lab.

BSCs should be located away from doors, windows that can be opened, and heavily traveled laboratory areas. This will help to minimize air pattern disruption in the cabinet. Air supply diffusers or exhaust vents should not be placed directly over or in front of BSCs where the movement of air can affect the airflow of the cabinet. A 12 inch clearance should be provided behind and on each side of a BSC to allow easy access for maintenance, and to ensure that the air return to the laboratory is not hindered. Open flames, such as gas burners, should not be used in a BSC.

Biosafety Level 2 (BSL-2) laboratories should have the vacuum lines used inside a BSC protected with High Efficiency Particulate Air (HEPA) filters, or their equivalent. These filters must be replaced as needed. Liquid disinfectant traps may be required.

All BSCs to be installed at USC should meet NSF Standard 49 requirements. The selection of cabinets should be based on an evaluation of the work to be performed and the specific safety requirements necessary to protect personnel, research, and the environment. Further guidance on the proper selection and installation of BSCs can be obtained from the most recent edition of *Primary Containment of Biohazards: Selection, Installation and Use of Biological Safety Cabinets*. This document is available online at http://www.cdc.gov/od/ohs/biosfty/bsc/bsc.htm.

Equipment:

A wide variety of laboratory equipment is used in USC laboratories. The goal is to create adaptability in laboratory space so that instruments can be relocated within the laboratory without altering the space or attendant utility systems and without compromising the operation of the instruments or safety of the users. Some instrumentation rooms (i.e. electron microscopy suites or mass spectrometry rooms) require special utilities and environmental controls.

Autoclaves:

A method for decontaminating all laboratory wastes should be available in the facility. For maximum flexibility, autoclave space is recommended on each floor, or at a minimum in a convenient location in each building, where microbiological research is performed. Actual installation of autoclaves and their use are an operational decision.

The architects and engineers should review the requirements of the building personnel and Environmental Health and Safety when designing and specifying autoclave space.

Autoclave space should be finished with epoxy coatings and should not have a suspended, acoustical ceiling. This area should be thoroughly caulked and sealed to promote cleanliness and reduce pest harborage.

The space should have adequate exhaust capacity to remove heat, steam, and odors generated by the use of the autoclave(s). The autoclave space should operate at negative pressure to the surrounding areas.

Gas Cylinders:

If gas cylinders are to be placed in the lab, they should be properly secured to a vertical surface or counter out of the way of traffic in the space. Appropriate space for such cylinders should be provided within the laboratory to minimize potential hazards associated with the use of these cylinders and to maximize usable laboratory space.

Flammable Chemicals and Waste Storage:

Flammable-chemical storage cabinets should be placed in each laboratory and meet applicable fire safety requirements. Flammable storage cabinets should not be located near exit doorways, stairways, or in a location that would impede egress. Space should be allocated in each laboratory for storage of chemical waste.

Fire Extinguishers:

The distribution of fire extinguishers is specified by fire code. For example, a fire extinguisher must be within 30 feet of a flammable liquid storage area. Extinguishers should be conspicuously located where they will be readily accessible in the event of fire. They should be located close to the exits from an area and along normal paths of travel. Fire protection and fire detection equipment should not be obstructed. Architects and engineers should consult with Fire Safety personnel regarding questions on the placement of fire extinguishers in laboratories.

Architectural Finishes and Materials

Design features and materials selected for the construction of laboratories should be durable, smooth, and cleanable, provide ease of maintenance and minimize pest access, and contribute to the creation of a comfortable, productive, and safe work environment. Materials for laboratory finishes should be as resistant as possible to the corrosive chemical activity of disinfectants and other chemicals used in the laboratory. Selection of materials and design of penetrations through walls and floors have an impact on fire safety in buildings.

Floor and Base Materials:

Floor materials should be non-absorbent, skid-proof, resistant to wear, and resistant to the adverse effects of acids, solvents, and detergents. Materials may be monolithic (sheet flooring) or have a minimal number of joints such as vinyl composition tile (VCT) or rubber tile. Floor materials should be installed to allow for decontamination with liquid disinfectants and to minimize the potential spread of spills.

Walls:

Wall surfaces should be free from cracks, unsealed penetrations, and imperfect junctions with ceiling and floors. Materials should be capable of withstanding washing with strong detergents and disinfectants and be capable of withstanding the impact of normal traffic.

Ceilings:

Ceilings such as washable lay-in acoustical tiles (Mylar face with smooth surface or equivalent) should be provided for most laboratory spaces. Open ceilings are acceptable provided minimal ducting and piping is present and all exposed surfaces are smooth and cleanable.

Windows and Window Treatment:

Windows should be non-operable and should be sealed and caulked. Window systems that use energy-efficient glass are recommended. Treatments should meet all functional and aesthetic needs and standards.

Doors:

Vision panels are recommended for all laboratory doors. In laboratories where the use of larger equipment is anticipated, wider/higher doors should be considered. Laboratory doors should be recessed and swing outward in the direction of egress. Door assemblies should comply with all appropriate codes. Biosafety Level 2 (BSL-2) laboratories should have doors that are self-closing and have locks.

Door Hardware:

Laboratory doors are considered high-use doors. All hardware should be appropriately specified to withstand this type of use. Light commercial grade hardware will not be specified. All appropriate hardware to meet security, accessibility, and life safety requirements should be provided.

Module/Bay Size:

The dimension of the structural bay, both vertical and horizontal, should be carefully evaluated with respect to the laboratory planning module, mechanical distribution, and future expansion plans. Because of the importance of the laboratory planning module to functional and safety issues, the laboratory planning module should be considered as the primary building module in multi-use facilities.

The horizontal dimension of the structural bay should be a multiple of the laboratory-planning module dimension to provide for maximum flexibility and regular fenestration and to allow uniform points of connection for laboratory services with respect to the laboratory-planning module. Columns should not fall within the laboratory-planning module to prevent interference with laboratory layouts and inefficient use of valuable laboratory space. Close coordination between structural and mechanical disciplines is critical to minimize interference of piping and ventilating systems with the structural framing.

Equipment Pathway:

The potential routing or pathway for the addition or relocation of heavy equipment should be reviewed and identified during the design phase.

Hazard Communication Signage:

Each laboratory should have a signage holder for prominently displaying hazard communication information at the entrance door. Individual labs should have signage holders that are consistent with the type used by other laboratories within each department or building.

Ventilation

HVAC systems should be responsive to research laboratory demands. Temperature and humidity should be carefully controlled. Systems should have adequate ventilation capacity to control fumes, odors, and airborne contaminants, permit safe operation of fume hoods, and cool the significant heat loads that can be generated in the lab.

HVAC systems should be both reliable and redundant and operate without interruption. Fume hoods will operate continuously. HVAC systems should be designed to maintain relative pressure differentials between spaces and should be efficient to operate, both in terms of energy consumption and from a maintenance perspective. Federal energy standards should be achieved.

Laboratory noise, much of it generated by HVAC systems, should be maintained at appropriate levels.

Air Quality:

HVAC systems should maintain a safe and comfortable working environment and be capable of adapting to new research initiatives. In addition, they should be easy to maintain, energy efficient, and reliable to minimize lost research time. Laboratory HVAC systems should utilize 100 percent outdoor air, conditioned by central station air handling systems to offset exhaust air requirements. Laboratory supply air should not be re-circulated or reused for other ventilation needs. Laboratories containing harmful substances should be designed and field balanced so that air flows into the laboratory from adjacent (clean) spaces, offices, and corridors. This requirement for directional airflow into the laboratory is to contain odors and toxic chemicals, i.e., negative pressurization. Air supplied to the corridor and adjacent clean spaces should be exhausted through the laboratory to achieve effective negative pressurization. The architects and engineers should develop in the design phase a formal startup and commissioning plan and procedure that addresses indoor air quality requirements.

Air Distribution:

Air supplied to a laboratory space should keep temperature gradients and air turbulence to a minimum, especially near the face of the laboratory fume hoods and biological safety cabinets. Air outlets should not discharge into the face of fume hoods. Large quantities of supply air can best be introduced through perforated plate air outlets or diffusers designed for large air volumes.

Relative Pressurization:

Laboratories should remain at a negative air pressure in relation to the corridors and other non-laboratory spaces. Laboratory air should flow from low-hazard to high-hazard use areas. Administrative areas in laboratory buildings should always be positive with respect to corridors and laboratories.

Air Balance:

Control of airflow direction in research laboratories controls the spread of airborne contaminants, protects personnel from toxic and hazardous substances, and protects the integrity of experiments. In these facilities, the once-through principle of airflow is applied on the basis of (1) exhausting 100 percent of the supplied air, (2) maintaining the required airflow with all exhaust units operating at capacity, and (3) providing directional flow of air from areas of least contamination to those of greatest contamination.

Ventilation Rates:

The ventilation rate for laboratory HVAC systems is driven by three factors: fume hood demand, cooling loads, and removal of fumes and odors from the general laboratory work area. The minimum air-change rate for laboratory space is six air changes per hour regardless of space cooling load. Some laboratories may require significantly higher rates to support fume hood demand or to cool high instrument heat loads in equipment laboratories. The design of the HVAC systems should allow for the maximum exhaust capacity for all biological safety cabinets which may be required in the facility.

Ventilation in Laser Laboratories:

Rooms where laser equipment is used should be properly ventilated to avoid buildup of ozone generated from the laser and mercury lamps. Other lasers need to be exhausted if they are using heavy metals.

Plumbing

The plumbing systems should be coordinated with the laboratory-planning module. A piping distribution method (i.e. mains, risers, and branch lines) should be designed to accommodate easy service isolation and system maintenance while minimizing disruption to laboratory functions. Piping systems should be designed for flexibility and have redundant components to provide reliable and continuous operation. Adequate fluid temperature, pressure, and volume should be delivered to required lab functions through conservatively sized pipe mains. Future capacity allowances need to be considered in building designs. Emergency isolation valves should be conveniently located on branch lines so that segments can be taken offline quickly in the advent of failures.

Sinks:

Laboratories must have a sink for hand washing. The sink may be manually, hands-free, or automatically operated. Biosafety Level 2 (BSL-2) laboratories should have the sink located near the exit door. When a separate tissue culture room is located within a main lab room, there should be a hand washing sink located inside the tissue culture room.

Emergency Showers and Eyewash Stations:

At least one emergency shower and eyewash station should be available in each laboratory. These emergency showers and eyewash stations should be tapped to the laboratory water supply. When installing showers, the pull handle should be located in direct proximity to the shower head. Safety showers should be no more than 25 feet from the chemical fume hood or other area where corrosive chemicals will be used. An eyewash station must be readily available in all Biosafety Level 2 (BSL-2) laboratories. When a tissue culture room is located within a main lab room, the eyewash station should be installed next to the hand washing sink located inside the tissue culture room.

Vacuum Systems:

Vacuum pump systems will have hydrophobic (water-resistant) filters on the suction side, with the exhaust to the outside of the facility. Vacuum system exhaust should be vented to the outside of the building and not re-circulated to the mechanical room. A sampling port may be needed to sample exhaust. Filter housing should be designed for easy replacement of the filter, with maximum protection for maintenance employees from possible contamination.

Vacuum systems should be protected with appropriate filtration (0.2 micron hydrophobic filter or equivalent) to minimize the potential contamination of vacuum pumps. Filters should be located as close as possible to the laboratory in order to minimize potential contamination of vacuum lines. Some mechanism for the decontamination of filters should be incorporated in the design of the vacuum system.

Electrical

Lighting:

Laboratory research requires high-quality lighting for close work, in terms of both brightness and uniformity. Fixtures should be positioned to provide uniform, shadow-free and glare-free illumination of the laboratory bench top.

General lighting for laboratories should be fluorescent fixtures. Fluorescent light fixtures should be directly above and parallel to the front edge of the laboratory bench to prevent shadows. Local wall switches should control light fixtures.

Lasers and X-Ray Machines:

If lasers or x-ray machines will be used in the lab, they will often require a source of electrical power that is more than the standard 110/120 volt circuit.

Alarm and Monitoring Systems:

The increasing sophistication and fine control of laboratory instruments and the unique quality of many experiments demand closely monitored and alarmed systems that can be connected to individual pieces of equipment or temperature-controlled rooms. Several excellent monitoring systems are available for this purpose. They can be connected to a central monitoring facility at several levels of observation or can be used internally within a laboratory setting. Architects and engineers should consult with the laboratory personnel and EH&S staff to evaluate the need for alarms and monitoring systems.

Radioactive Materials Laboratories

There are several additional considerations that should be evaluated for labs that will be using radioactive materials. These labs must have restricted access to prevent the general public from receiving radiation exposures. The lab must have a lock on the outside door and have lockable storage areas. An area of the laboratory must also be designated for the storage of radioactive waste, and this area should be in a location where traffic is minimal to prevent radiation exposure to lab employees and visitors.

The ventilation system must be under negative pressure relative to the surrounding areas. All air from the lab should be vented through the fume hood and must not be re-circulated. The fume hood must be constructed of smooth, impervious, washable and chemically resistant materials. The working surface must be strong enough to bear the weight of any shielding material that may be required. The working surface must have slightly raised edges to contain any spills. The hood should be installed to maintain an average face velocity between 125 – 150 feet per minute (FPM). The fume hood exhaust must be located on the roof of the building with the discharge point high enough to ensure acceptable dilution, dispersion and elimination of unacceptable re-entry through building openings.

The sinks must be made of material that is readily decontaminated. Sink traps must be accessible so that they can be surveyed with a Geiger counter. These traps are usually located in the cabinet under the sink.

No provisions should be made for food or beverage preparation or storage in the laboratory. Desks and study facilities should not be located in an area where radioactive materials will be handled.