## SPECIALIZED FACILITIES

Washington University School of Medicine (WUSM) Specialized Facilities addresses the following requirements for WUSM projects:

**LABORATORY OVERVIEW**
**GENERAL LABORATORIES AND BIOSAFETY LEVEL 2 (BSL-2)**
**BIOSAFETY LEVEL 3 / ANIMAL BIOSAFETY LEVEL 3 (A/BSL-3)**
**SAFETY EQUIPMENT**
**ARCHITECTURAL CONSIDERATIONS**
**CERTIFICATION AND MAINTENANCE**

The Design Team shall coordinate items in the following section with EH&S and WUSM Project Manager, including completion of the Checklist for Project Management, early in the design process. EH&S shall participate in the coordination and development of design in Schematic Design and Design Development phases, and be included in the Final Review Meeting of the Construction Document phase.

References:

ABSA International (ABSA)

American National Standards Institute (ANSI)

Biosafety in Microbiological and Biomedical Laboratories (BMBL)

Centers for Disease Control and Prevention (CDC)

Code of Federal Regulations (CFR)

Guide for the Care and Use of Laboratory Animals International Safety Equipment Association (ISEA)

National Fire Protection Agency (NFPA)

National Institutes of Health (NIH)

NIH Design Requirements Manual (DRM)

2016 National Sanitation Foundation (NSF)

Occupational Safety & Health Administration (OSHA)

Washington University Biosafety Officer (BSO)

Washington University Division of Comparative Medicine (DCM)

Washington University Institutional Biological and Chemical Safety Committee (IBC)

Standards References:

GENERAL INFORMATION – DESIGN PHASES: PROCESS

EQUIPMENT – LABORATORY FUME HOODS

MECHANICAL – LABORATORY FUME HOODS

MECHANICAL – DDC CONTROLS

PLUMBING - FIXTURES

## LABORATORY OVERVIEW

DESIGN GUIDELINES

1. Research laboratories should be designed to address the hazards that are inherent or anticipated in such facilities. The design team must address the following major hazards that are encountered in research laboratories:
    a. Biological: etiological agents, clinical and other materials that may contain etiologic agents, biological toxins.
    b. Chemical: carcinogens, mutagens, teratogens, toxic chemicals, flammables, compressed gases, corrosives.
    c. Physical: lasers, magnetic fields, high voltage, ultraviolet light, high noise levels, electromagnetic fields, vibration.
    d. Radioactive: radionuclides, equipment that produces ionizing radiation.
2. The methods of handling these hazards in the laboratory are critical to the laboratory design. Therefore, the risk of each hazard must be individually assessed during the design process and appropriate measures must be taken for proper storage, handling, and disposal of hazards. Regulations, guidelines, and standards developed to address these concerns are referenced throughout this document.
3. Biological Safety Level 1 (BSL-1) represents a basic level of containment that relies on standard microbiological practices with no special primary or secondary barriers recommended, other than a sink for handwashing. These laboratories are suitable for work involving well-characterized agents not known to consistently cause disease and present minimal potential hazard to laboratory personnel and the environment. Special containment equipment or facility design is not required, but may be used as determined by appropriate risk assessment.
4. Biological Safety Level 2&3 (BSL-2/3) laboratories are those in which work is done with a broad range of indigenous, moderate-risk infectious microorganisms that are normally present in the community and considered by CDC/NIH to be Risk Group 2 or 3 pathogens (reference CDC/NIH Bio- safety in Microbiological and Biomedical Laboratories (BMBL)). Biological safety cabinets may be required when procedures with the potential for creating aerosols are conducted. Because research with Risk Group 2 or 3 pathogens sometimes involves the other major hazards listed in the introduction, all aspects of safety must be coordinated in the design of the laboratory.

5. If radionuclides are used, specific guidelines for safe containment may be obtained from the WU Department of Radiation Safety. If hazardous chemicals or any of the physical hazards are involved, safety guidelines and relevant regulations for safe containment may be obtained from WU Environmental Health & Safety (EH&S) and the St. Louis City Fire Department.
6. Common Terms:
    a. Aerosol: a suspension in air of liquid or solid particles typically less than five microns in diameter.
    b. Class II Biological Safety Cabinet (BSC): a ventilated enclosure for personnel, product, and environmental protection. It is characterized by a protective laminar flow air barrier and HEPA-filtered supply and exhaust air. The purchase of new biological safety cabinets is covered under specification requirements.
        - Class II, Type A1 BSC: recirculates the exhaust air into the laboratory space after filtration.
        - Class II, Type A2 BSC: recirculates the exhaust air into the laboratory space after filtration or exhausts air to the outside through a thimble connection.
        - Class II, Types B1 and B2 BSC: exhausts air to the outside, after filtration, via sealed ducts and an external fan.
    c. Containment: a safe method of managing infectious agents within the laboratory environment to prevent their escape from the laboratory.
    d. Decontamination: a procedure that eliminates or reduces microbial contamination (or toxic substances) to a safe level with respect to transmission of infection (or toxicity).
    e. EH&S: Washington University School of Medicine (WUSM) Office of Environmental Health & Safety.
    f. Guidelines: design recommendations detailing best practice, issued by governmental agency through formal legal constructs.
    g. Regulations: design requirements mandated by a government agency through formal legal constructs.
    h. Standards: design recommendations published by recognized national safety organizations (e.g., National Fire Protection Agency (NFPA), ABSA International (ABSA), National Sanitation Foundation (NSF)) as being the best practice. Standards may be incorporated into governmental codes.

**GENERAL LABORATORY AND BIOSAFETY LEVEL 2 (BSL-2)**

DESIGN GUIDELINES

1. The following General Laboratory Design Guidelines are intended to assist WUSM and its stakeholders with programming and design of new General Laboratory and Biosafety Level 2 (BSL-2) facilities.

REQUIREMENTS

1. General Laboratory and BSL-2 Design Features:
    a. Directives: Recommendations with respect to best practices within a university laboratory, based on nationally accepted laboratory safety guidelines and standards, issued by EH&S.
    b. The interior surfaces of the laboratory walls, floors, and ceilings shall be water resistant and easily cleanable.
        - Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities
        - Justification: The walls should be painted and sealed in a manner that facilitates washing in the event of a splash. Wooden and wood finish walls or floors are prohibited because they can absorb potentially infectious material and make decontamination impossible. The floors shall be solid slab or seamless sheet vinyl. A continuous floor reduces the potential of liquid absorption. Covings are required to facilitate clean-up. Tiles and wooden planks are prohibited. Perforated acoustical ceiling tiles are prohibited.
    c. Bench tops shall be impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.
        - Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities
        - Justification: BSL-2 manipulations can involve concurrent use of chemical solvents such as formaldehyde, phenol, and ethanol, as well as corrosives. The laboratory bench must be resistant to the chemical actions of these substances and disinfectants. Wooden bench tops are not appropriate because an unfinished wood surface can absorb liquids. Also, wood burns rapidly in the event of a fire. Fiberglass is inappropriate since it can degrade when strong disinfectants are applied. Fiberglass also releases toxic smoke when burned.
    d. Laboratory furniture shall be sturdy. Spaces between benches, cabinets, and equipment shall be accessible for cleaning.
        - Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities
        - Justification: Laboratory furniture should have smooth surfaces to resist the absorption of liquids and the harsh effects of disinfectants. Furniture must not be positioned in a manner that makes it difficult to clean spilled liquids or conduct routine maintenance. For example, positioning a Class II BSC in a limited concave space might not allow the biosafety cabinet

certifier to remove panels of the cabinet when recertifying the unit. Shelving above a BSC is prohibited within an 18-inch vertical distance from the exhaust filter housing to facilitate filter maintenance.

e. Each laboratory shall contain a sink for hand washing near the exit door. Sinks constructed of stainless steel are optional.

- Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities
- Justification: Chemicals and certain pathogenic organisms can be transferred by hand contact to mucous membranes or to other surfaces in the laboratory. It is extremely important to wash hands often and before leaving the laboratory. For the latter reason, the sink shall be located close to the egress.

f. Windows in the laboratory that open to the exterior are not recommended. If the laboratory does have windows that open to the exterior, they must be fitted with screens.

- Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities

g. Laboratory doors should be self-closing and have locks.

- Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities

h. The laboratories shall have inward directional airflow and continuously maintain a negative pressure in relation to areas such as corridors or any adjacent spaces. Recirculation of lab air to spaces outside the laboratory is not permitted.

i. Room pressure is to be controlled by volumetric offset (typically between 75-100 CFM).
ii. Room pressure monitoring is not specifically required; however, the design team shall discuss with the University for each project to determine if room pressure monitoring is desired for the project and document accordingly. If required, see section A/BSL-3 HVAC Systems for product requirements.

i. An eyewash station shall be readily available. Provide tempered water at all eyewash stations.

- Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities, OSHA – 29 CFR 1910.151 (c)
- Standard: ANSI / ISEA Z358.1
- Justification: Many microorganisms can infect via the mucous membrane route. Certain chemicals can cause injury If splashed into the eyes. Therefore, eyes shall be flushed thoroughly after splashes and accidents infecting the eyes.

j. In addition, an autoclave for decontaminating infectious laboratory waste should be available in the building for BSL-2 laboratories.

- Guideline: CDC/NIH BMBL; BSL-1/2, D. Laboratory Facilities
- Justification: An autoclave is necessary to decontaminate all living forms of infectious agents, including spores that resist chemical decontaminants.

**BIOSAFETY LEVEL 3 / ANIMAL BIOSAFETY LEVEL 3 (A/BSL-3)**

DESIGN GUIDELINES

1. The following A/BSL-3 Design Guidelines are intended to assist WUSM and its stakeholders with programming and design of new Biosafety Level 3 (BSL-3) and Animal Biosafety Level 3 (ABSL-3) facilities. These guidelines were developed specifically for the requirements of high containment facilities, for both laboratory and animal facilities.
2. These guidelines are based on input from several sources, including the following:
    a. Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th Edition
    b. NIH Design Requirements Manual (DRM), 2016
    c. USDA ARS Facility Design Standards, 2012
    d. Guide for the Care and Use of Laboratory Animals, 8th Edition
    e. Industry Standards and Best Practices
3. The information contained herein is only one element of the process required to develop the appropriate design and engineering systems for A/BSL-3 containment facilities. The operational protocols and procedures are a critical component of the development of the design and must be included in the final evaluations. Principal Investigators, Administrators, and Biosafety Professionals must be included in conducting risk assessments, preparing and documenting the operational procedures, and providing input into selecting the appropriate engineering controls and systems required to mitigate the risks.
4. These Design Guidelines are intended to provide design teams with the tools and information needed to complete future A/BSL-3 facilities at WUSM, and therefore attempt to cover all the options that could be considered for these types of spaces. Even though a broad range of requirements are listed, architectural and engineered systems should not be selected where they are not needed (i.e. *"one size does not fit all"*). WUSM may choose to include engineering controls that are not required by a given type of research, but that may provide WUSM with the ability to adapt to future research requirements. Final selection of controls and systems should be reviewed with WUSM stakeholder representatives from Operations and Facilities Management as well as Environmental Health & Safety.
5. It is not the intent of these Design Guidelines to require the retro-active upgrades to existing A/BSL-3 spaces, but to provide guidance going forward with new facilities. However, any issues identified in existing spaces that impact the safe operation of these facilities which may result in harming the health and well-being of faculty, staff, students, visitors, or the

environment should be addressed accordingly.

REQUIREMENTS

1. A/BSL-3 laboratories and animal facilities are those in which activities are conducted with infectious material that may cause serious disease through inhalation, there is an increased risk of personal exposure via aerosol generating manipulations, and / or the Institutional Biological and Chemical Safety Committee (IBC) or Biosafety Officer (BSO) has determined the activities warrant the use of high containment facilities and practices.
2. All new laboratory facility projects, laboratory usage, and agents to be used will be evaluated by EH&S in conjunction with oversight by the IBC and the completion of a through risk assessment.
3. All manipulations of infectious agents within A/BSL-3 facilities shall be conducted within biosafety cabinets (BSCs) or other appropriate primary containment equipment / devices.
4. Consideration for decontamination of surfaces, equipment, and the facility itself should take into account the infectious agent in use, required contact time of decontamination agent, and material compatibilities, as well as any other factors deemed appropriate for the risk assessment. Any decontamination process should be evaluated and verified by EH&S on a project-specific basis.
5. All critical equipment shall be tied to the Building Automation System (BAS) to allow for constant monitoring and alarming. Critical equipment may include air-handling units, exhaust fans, differential pressure monitors, terminal units, -80 degree C freezers, IVC Racks, walk-in cold rooms, incubators, or other devices deemed necessary to maintain the safe and secure operation of the A/BSL-3 laboratory.
    a. All controls specifically for A/BSL3 systems (air valves, room pressure monitors, dedicated supply and/or exhaust air handling systems, trim humidifiers, etc.) shall be on the Johnson Controls system.
    b. All HVAC equipment and controls shall be located outside the containment boundary if possible.
6. A/BSL-3 Design Features:
    a. Directives: Requirements with respect to best practices within a university laboratory, based on nationally accepted biosafety guidelines and standards, issued by EH&S.
    b. A/BSL-3 entry must be through two interlocking (mechanical or procedural), inward opening, self-closing doors. Methods for restricting access to only those individuals with demonstrated need, proper clearance, and training must be in place. Notices should be posted outside the first door to notify potential entrants of the hazards contained within and measures they must take to protect themselves.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Regulation (for Select Agent use only): 42 CFR Part 73, 9 CFR Part 121, 7 CFR Part 331
- Justification: The risk of potential exposure in high containment spaces and the regulatory requirements for access to Select Agent spaces require that only those individuals with demonstrated need and proper preparation be allowed access to high containment spaces. Interlocking double-door access is necessary to ensure that the interior of the laboratory is never exposed to any common area.

c. The interior surfaces of the A/BSL-3 laboratory shall be impervious to water and resistant to chemical disinfectants intended for use in the space.

   i. Walls and ceilings shall be high impact, water resistant gypsum board or concrete masonry units (CMU) with epoxy paint coating of fiberglass reinforced panels (FRP).

   ii. All penetrations should be sealed airtight.

   iii. Floors should be epoxy with integral cove base in A/BSL-3 rooms or welded sheet vinyl with integral cove in BSL3 rooms.

   iv. Doors should be chemical resistant coated metal.

   - Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
   - Justification: Due to the highly pathogenic nature of the microorganisms frequently encountered in A/BSL-3 laboratories, the efficacy of disinfection and decontamination procedures must be ensured without compromising the integrity of the facility. Surfaces that absorb water or degrade in the presence of chemical disinfectants are not suitable for an environment that will be repeatedly exposed to both. Sealed surfaces and floor coving are recommended to reduce the number of cracks or crevices that may harbor microorganisms during application of a disinfectant or decontaminant.

d. Bench tops and other work surfaces such as the work space inside a Biosafety Cabinet (BSC) shall be impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.

   - Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
   - Justification: Activities within a A/BSL-3 laboratory can involve concurrent use of chemical solvents such as formaldehyde, phenol, and ethanol as well as corrosives or other reactive chemicals. The laboratory bench or BSC work surface must be resistant to the chemical actions of these substances as well as disinfectants used to inactivate the organisms under study. Wooden or other porous or combustible bench tops are not appropriate because even finished wooden surfaces can absorb liquids or ignite in the event of a fire. Fiberglass is inappropriate since it can degrade in the presence of some chemicals; it also produces toxic smoke if burned.

e. Laboratory furniture shall be sturdy and not upholstered with absorbent materials. Space shall be left between benches, cabinets, and equipment to allow access for cleaning / decontamination and maintenance.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: Laboratory furniture must not be absorbent so that it may be decontaminated effectively. Space must be left between furniture to allow for the cleaning and maintenance of devices as required (i.e. biosafety cabinets).

f. Any windows in the A/BSL-3 laboratory shall be permanently sealed.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: To maintain proper pressure differential and directional airflow, to prevent egress of aerosols, particularly during space decontamination, to the surrounding spaces or environment, and to assist with pest control.

g. A/BSL-3 spaces located on a building exterior wall should have a positively pressurized interstitial space between the occupied areas and the exterior wall. The depth of the interstitial space should allow adequate access to MEP equipment and maintenance of the exterior wall.

- Guideline: BSL-3 Best Practices
- Justification: To prevent the intrusion of exterior moisture and contaminants.

h. Any penetrations into the laboratory should be avoided or minimized; however, when required (i.e. for ductwork, electrical conduits, sprinkler piping, gas piping, fire alarm, etc.), they should be fully sealed (or sealable) with particular consideration of decontamination processes.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: To maintain proper pressure differential and directional airflow and to prevent egress of aerosols, particularly during space decontamination, to the surrounding spaces or environment.

i. An appropriate method for solid waste decontamination, which has been selected and validated based on the risk assessment and EH&S input, must be available (i.e. autoclave) within the facility and if possible, within the A/BSL-3 laboratory suite / space.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Regulation (for Select Agent use only): 42 CFR Part 73, 9 CFR Part 121, 7 CFR Part 331
- Justification: Effective waste management and disposal ensures proper decontamination of infectious and contaminated material to mitigate potential releases and exposures to personnel, community, or the environment.

7. A/BSL-3 Heating, Ventilation, and Air Conditioning (HVAC) System Features:

a. The room shall have a fully ducted mechanically generated ventilation system. All supply air to the suite shall be 100% outside air. All air from the suite shall be 100% exhausted via dedicated exhaust with no recirculation to other building areas. Exhaust air should be dispersed away from occupied areas and from building intake locations.

    i. All HVAC equipment selections shall produce a product the operates in a stable condition in both single mode or parallel mode.

    - Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
    - Justification: Recirculated air is not permitted to eliminate any possibility of potentially contaminated air entering other building spaces such as in the event of a failure in one of the containment systems.

b. Dedicated A/BSL-3 exhaust fans shall be provided in an N+1 configuration, where "N" is the number of components to handle the airflow. Both the primary and redundant fan shall operate simultaneously at reduced speed to maintain directional airflow. Upon a failure of one fan, the remaining fan(s) shall be capable of providing the design airflow rate.

    i. High-plume exhaust fans are preferred due to outdoor location and available shared plenum.

    ii. Design static pressure performance for each exhaust shall be increased beyond minimum pressure requirements to allow the HEPA filter assembly to be changed at less frequent intervals than non-A/BSL-3 suite HEPA filters.

    - Guideline: BSL-3 Best Practices
    - Justification: To ensure near 100% reliability of the exhaust system per Guide requirements.

c. Where dedicated supply air handling units are deemed necessary by the risk assessment or regulatory requirement (for A/BSL-3), they should be provided in an N+1 configuration, where "N" is the number of components to handle the load. The redundant air handling unit shall automatically start upon failure of the primary air handling unit.

    - Guideline: BSL-3 Best Practices
    - Justification: Minimize downtime of system to meet the Guide requirements.

d. Dedicated A/BSL-3 supply air handling units shall be hardwired interlocked with exhaust fans to prevent reversal of airflow. Upon a total exhaust system failure, the air handling units fans shall automatically be shut down.

    - Guideline: BSL-3 Best Practices
    - Justification: No reversal of airflow.

e. There shall be no positive pressure exhaust ductwork in occupied spaces, including mechanical rooms. Any pre-existing conditions that do not meet this requirement should be mitigated appropriately (i.e. mechanically sealed ductwork, relocate fan to

the roof, etc.)

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: Positive pressure ductwork inside occupied spaces is not permitted to eliminate any possibility of potentially contaminated air entering building spaces in the event of a breach or failure in the ductwork.

f. The laboratories shall have inward directional airflow and continuously maintain a negative pressure (-.05" water column, but not less than -0.03" w.c.) in relation to areas such as corridors, anterooms, or any adjacent spaces.

i. Room pressure is to be controlled either by volumetric offset (typically between 75-100 CFM) or by pressure differential control. The method of room pressure control shall be discussed and agreed upon by the A/E and the University during the design phase.

ii. Differential pressure across doors may be greater than 0.05" w.c. if the door is spanning across more than one pressure zone.

- Guideline: NIH Design Requirements Manual; BSL-3 Best Practices
- Regulation (for Select Agent use only): 42 CFR Part 73, 9 CFR Part 121, 7 CFR Part 331
- Justification: Negative air pressure between rooms produces the directional airflow necessary to contain potentially contaminated aerosols, 0.05" WG is typically within the operating range of most HVAC components and sensors and provides containment during common events such as doors opening and personnel ingress / egress.

g. Provide HEPA filter exhaust registers.

i. All exhaust shall be HEPA filtered.

ii. The use of HEPA filters in the exhaust registers shall be discussed and agreed upon by the A/E and the University (including EH&S and DCM) during the design phase.

iii. The sizing of exhaust fans shall take into consideration all filters (prefilters and HEPA filters) that may be installed in the system including at the exhaust registers and at a common HEPA filter unit.

- Directive: EH&S, BMBL, Guide for the Care and Use of Laboratory Animals
- Regulation (for Select Agent use only): 42 CFR Part 73, 9 CFR Part 121, 7 CFR Part 331
- Justification: Enhanced engineering controls, such as HEPA-filtered exhaust, are necessary to prepare the space for the potential need in future research. Providing HEPA-filtered exhaust (or the capability to do so, e.g. installing HEPA filter housings but not using HEPA filters until required) affords greater flexibility and adaptability of the A/BSL-3 laboratory spaces.

h. The ventilation system shall utilize pressure independent airflow control valves.

   i. Each room shall have a dedicated supply and exhaust air valve.

   ii. Airflow control valves shall be designed for either passive control with fixed airflow offset or differential pressure control such that the supply air valve tracks the exhaust air valve to maintain negative pressure.

   iii. Each room shall have an independent controller, unless dictated otherwise by a regulatory agency (i.e. USDA) wherein fast-acting valves with interval differential pressure switches (or equivalent) will be used.

   - Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
   - Justification: To maintain directional airflow under failure scenarios, control valves must be in place to compensate for changing system pressures. With airflow offset control, doors must be designed to allow air to flow into room to maintain directional airflow. As an option, if doors are too tight, barometric damper in door or wall of room can be provided.

i. An exhaust canopy shall be provided over the unload side of double door pass-through autoclaves. Consideration should be given to providing an exhaust canopy over the load side of the double door pass-through autoclaves based on factors such as frequency of use, concerns over disruption of airflow patterns, etc.

   - Guideline: BSL-3 Best Practices
   - Justification: Steam and heat shall be removed at the source. The amount of heat and steam produced by an autoclave can undo the air balance in a room or disrupt airflow by changing convection currents, and compromise containment.

j. Laboratory and equipment storage should not block fire sprinkler heads or supply / exhaust grilles, and should be placed at a minimum distance of 18” or otherwise specified by applicable fire code, whichever distance is shorter. Supply and return air grilles should not be located directly in front of vent hoods or BSCs.

   - Directive: City and County Fire and Building Code
   - Guideline: BSL-3 Best Practices
   - Justification: Many supply diffusers and room exhaust grilles are located along laboratory walls. High storage of boxes may impede the circulation of air and hinder the functionality of air supply and exhaust.

k. Sound control from mechanical systems relative to the laboratory space shall be maintained below room criteria (RC) of 45 dB.

   - Directive: DCM and OSHA Action Level
   - Guideline: BSL-3 Best Practices
   - Justification: Noise levels above room criteria (RC) 45 dB interfere with voice communication and increase the risk of accidents within the

laboratory.

l. All energy recovery devices in the exhaust airstream must be kept downstream of the HEPA filter. Energy recovery devices that have any potential for cross-contamination (i.e. energy recovery wheels) are not permitted.

- Directive: BSL-3 Best Practices
- Justification: Energy Conservation

m. An electronic air pressure monitor must be provided to provide personnel with a visual means to verify directional airflow. Baulin-tube pressure indicators ("ping pong" ball type) or magnehelic gauges are not permitted.

i. As a minimum, air pressure monitors shall be placed at the entry airlock (anteroom) into the A/BSL-3 suite on the corridor (clean) side and at the entry door into each A/BSL3 laboratory.

ii. The air pressure monitor shall have a range of -0.5" w.c. to +0.5" w.c.

iii. Air pressure monitor shall be Phoenix APM-II or approved equal.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: Indicates proper functioning of laboratory ventilation system.

n. Audible and visual alarms shall be placed in the lab suite to alert the users of airflow disruption. Audible and visual alarms must be programmable to facilitate the type of research being conducted in the space. Division of Comparative Medicine (DCM) or governing body shall be consulted in the design and installation of alarm system notification devices since careful consideration is necessary so as not to negatively impact research activities (i.e. animal welfare in A/BSL-3 spaces).

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities, Guide for the Care and Use of Laboratory Animals.
- Justification: Users must be aware of directional airflow disruptions so that aerosol generating procedures are not performed without the protection provided by directional airflow in the laboratory.

o. Locate all equipment requiring access and maintenance outside the containment zone. (In extreme circumstances, equipment that is required to be installed above ceilings in containment zone must be provided with a fully gasketed access panel; the number of access panels shall be minimized).

- Directive: BSL-3 Best Practices
- Justification: Safety precautions for maintenance personnel.

p. Bioseal dampers must be provided in supply and exhaust ducts to each room. Damper shall be capable of bubble tight shut-off at minimum 10" wc.

i. The bioseal damper in the supply duct shall be automatic.

ii. The bioseal damper in the exhaust may be either manual or automatic.

iii. Manual bioseal dampers shall be gear-operated, in lieu of, quarter turn handle.

iv. Edge seal on damper shall be compatible with decontamination agent to be used (silicone for VHP).

v. Locate bioseal damps as close as practical to the biocontainment boundary of the A/BSL-3 suite.

- Guideline: BSL-3 Best Practices
- Justification: In the event of a loss of exhaust, these are installed to prevent the A/BSL-3 from going into positive pressure mode. They also aid in decontamination of individual laboratories by isolating airflow. Dampers shall be located outside of containment zone.

q. Supply Ductwork:

i. To the bioseal shall at minimum be galvanized construction.

ii. Should be fully-welded stainless steel construction from the bioseal damper to the air device.

iii. Shall be constructed to withstand the maximum pressure capable in the system but not less than 4" w.c.

iv. All ductwork down stream of the HEPA filter shall be welded stainless steel.

- Guideline: BSL-3 Best Practices
- Justification: Minimize any leakage in ductwork to containment zone and for safety precautions of maintenance personnel.

r. Exhaust Ductwork:

i. From the room to the bio seal damper shall be fully welded, stainless steel construction.

ii. In cases where a HEPA filter may not be installed in the exhaust registers, exhaust ductwork from the registers to the common HEPA filter unit shall be fully welded, stainless steel construction.

iii. From the bioseal damper to the exhaust fan shall maintain the stainless steel construction.

iv. Exposed to the outside elements shall be wrapped, covered, or of stainless steel construction.

v. Shall be constructed to withstand the maximum pressure capable in the system but not less than 4" w.c.

vi. From the HEPA filter to the exhaust fan may be galvanized.

- Guideline: BSL-3 Best Practices
- Justification: Minimize any leakage in ductwork to containment zone and for safety precautions of maintenance personnel.

s. Supply airflow shall be the greater of the following:
   i. Calculated airflow required to meet room load calculation results with end users temperature and humidity requirements.
   ii. Minimum 8 air changes per hour for laboratories and procedure rooms.
   iii. Minimum 12 air changes per hour for animal holding rooms.
   - Guideline: BSL-3 Best Practices
   - Justification: Maintain proper air changes in laboratories.

t. Diffusers and grilles shall be one piece aluminum construction (or otherwise specified based on selected space decontamination method) or have fully welded back pans.
   i. Supply diffusers should be designed such that the throw velocity is less than 25 FPM five-feet from any part of adjacent biological safety cabinet.
   - Guideline: BSL-3 Best Practices
   - Justification: Minimize leakage from containment zone into ceiling cavity.

u. For HEPA filter installation, the system shall contain the following components in order of airflow:
   i. Automatic bioseal damper on supply side (as described above).
   ii. Decontamination port for decontamination of HEPA unit.
   iii. Inlet transition from round bioseal damper to rectangular HEPA module.
   iv. Bag-in, bag-out 30% pre-filter.
   v. Bag-in, bag-out, knife-edge, gel-seal.
   vi. HEPA filter test section for verification of integrity of installed HEPA filter.
   vii. Outlet transition from rectangular HEPA module to round bioseal damper.
   viii. Decontamination port for decontamination of HEPA unit.
   ix. Manual bioseal damper on exhaust side (as described above).
   x. HEPA filter module shall be of fully welded stainless steel construction.
   xi. Sloped-roof style shall be used if HEPA filter module is housed outdoors.
   xii. Double wall insulated unit shall be used if located outdoors.
   xiii. Differential pressure (Dp) sensor monitored by DDC system.
   - Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
   - Justification: Maintain operation and control of the room during shut down events.

v. The A/BSL-3 facility basis of design, WUSM commissioning / re-commissioning protocols, operational parameters, and procedures must be verified and documented prior to operation. Operational parameters must be verified and documented annually.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: Ensure system operates as designed in a safe and reliable manner.

8. A/BSL-3 Plumbing System Features:

a. Emergency showers that are located within the suite shall **not** have an associated floor drain nearby. Showers required by regulation may require shower water to be contained in a holding tank for later decontamination.

i. Provide tempered water at all emergency showers.

- Guideline: BSL-3 Best Practices
- Justification: All contaminated liquids are required to be decontaminated prior to disposal.

b. If there is a central vacuum system, two in-line hydrophobic (water-resistant) HEPA filters must be placed near each use point.

i. Filters must be installed to permit in-place decontamination and replacement.

ii. Liquid disinfectant traps are required.

iii. Local filters are to be provided by the end user on the suction side of the pump.

iv. All vacuum exhaust shall be outside the building.

v. If a system filter is used, a way for decontamination of the house vacuum lines shall be incorporated.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: Safety precautions of maintenance personnel.

c. Hands-free (electronic sensor) hand washing sinks are required prior to exiting the A/BSL-3 laboratory area (i.e. within the anteroom after doffing lab-specific personal protective equipment). If the suite is segregated into multiple areas, hand washing sinks are required at the exit point of each area. Sensor shall be set for 180 seconds (adj) of water flow upon activation.

- Guideline: CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: Numerous pathogenic organisms can be transferred by hand contact to mucous membranes or other surfaces in the laboratory. It is extremely important to wash hands often and before leaving the laboratory. For the latter reason, the sink shall be located close to the egress.

d. An eyewash station shall be readily available. Provide tempered water at all eyewash stations.

- Guideline: ANSI / ISEA Z358.1
- Justification: Numerous microorganisms are infectious if exposed to the mucous membranes around the eye. Therefore, eyes shall be flushed thoroughly after splashes and exposures to the eyes.

e. Atmospheric contained drain system typically services sink and floor drains.

i. Regulations require that drain traps are always filled with water or suitable liquid disinfectant.

ii. Traps within this system should have extra depth, a total of 2" WC greater than maximum static pressure generated by HVAC supply or exhaust, to prevent trap from being cleared in event of HVAC/exhaust system malfunction.

iii. Drain vents should be HEPA filtered. All plumbing materials should be compatible with the disinfectants used in laboratories, especially bleach which is the most commonly used disinfectant in BSL3 laboratories.

- Standard: CDC/NIH BMBL
- Justification: Safety precautions for maintenance personnel.

9. A/BSL-3 Fire Protection System Features:

a. Gasketed sprinkler heads with sealed housing shall be used to maintain the airtight construction of the ceiling system. Gasket material shall be compatible with the decontamination agent to be used. Sprinkler heads shall have a protective enclosure to prevent accidental impact.

- Guideline: BSL-3 Best Practices
- Justification: To maintain the integrity of the containment barrier and prevent air leakage.

10. A/BSL-3 Lighting System Requirements:

a. All recessed lighting shall be gasketed at the ceiling penetration. Gasket material shall be compatible with the decontamination agent to be used.

- Guidelines: NIH Design Requirements Manual (DRM), Guide for the Care and Use of Laboratory Animals, CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: To maintain the integrity of the containment barrier and prevent air leakage.

b. Light fixture material shall be stainless or aluminum as required to withstand the decontamination chemicals. Fixtures shall be surface mounted or recessed, fully sealed, enclosed, gasketed and UL Listed for damp locations. Lenses shall be acrylic prismatic.

- Guidelines: NIH Design Requirements Manual (DRM), Guide for the Care and Use of Laboratory Animals, CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: To maintain the integrity of the containment barrier and prevent air leakage.

c. For areas where there is high water usage (i.e. laboratory animal housing), light switches shall be weatherproof, corrosion resistant, stainless steel cover with a sealed rubber gasket.

- Guidelines: NIH Design Requirements Manual (DRM), Guide for the Care and Use of Laboratory Animals
- Justification: To eliminate electrical hazards.

d. Light fixtures should be installed in easily accessible locations. Refrain from placing lights above equipment locations. Review layout with WUSM Project Manager.

- Guidelines: NIH Design Requirements Manual (DRM), Guide for the Care and Use of Laboratory Animals
- Justification: To eliminate electrical hazards and provide easy access for maintenance.

11. A/BSL-3 Power System Requirements:

a. Emergency power shall be utilized on the following equipment as a minimum:

i. Dedicated supply and/or exhaust fans and controls serving the A/BSL-3 suite.

ii. All monitoring equipment and controls, both for any lab equipment and HVAC equipment.

iii. One light fixture per lab space.

iv. Specialized equipment designated by the end user, i.e. Biological Safety Cabinets (BSCs), specimen refrigerators, freezers, incubators, Inhalation Exposure Systems or other specialized equipment designated by the end user as coordinated by WUSM PM and EH&S.

- Guidelines: Guidelines: NIH Design Requirements Manual (DRM), Guide for the Care and Use of Laboratory Animals, CDC/NIH BMBL; BSL-3, D. Laboratory Facilities
- Justification: In the event of power failure, an alternative or emergency power source should be available to maintain critical services and support functions in animal rooms, operating suites, and essential areas.

b. All backboxes shall be cast metal, water-tight, gasketed, and have a threaded hub. Conduit penetrations into the backbox shall be sealed at the threaded hub.

i. This requirement applies to all spaces within the A/BSL3 suite including

A/BSL3 labs, animal holding rooms, procedure rooms, and all associated support spaces (anteroom, tank room, work room, corridor, etc.)

ii. If cast metal boxes are not available for the room pressure monitors (APM's), an alternate wall box will be acceptable if the cover plate of the room pressure monitor is gasketed such that the cover plate provides an air-tight seal.

- Guidelines: NIH Design Requirements Manual (DRM), BSL-3 Best Practices
- Justification: To maintain the integrity of the containment barrier and prevent air leakage.

c. All conduits shall be sealed airtight internally at the containment boundary.

- Guidelines: NIH Design Requirements Manual (DRM), BSL-3 Best Practices
- Justification: To maintain the integrity of the containment barrier and prevent air leakage. To facilitate pest control.

d. Receptacles shall be corrosion and moisture-resistant with a neoprene gasket and stainless steel cover as a minimum.

- Guidelines: NIH Design Requirements Manual (DRM), Guide for the Care and Use of Laboratory Animals, BSL-3 Best Practices
- Justification: To maintain the integrity of the containment barrier and prevent air leakage.

12. Fire Alarm:

a. Fire alarm strobes shall be present in each A/BSL3 lab space. Fire alarm horns should not be used, as they startle people and/or animals, and increase the risk of accidents.

## SAFETY EQUIPMENT

### DESIGN GUIDELINES

1. Biological safety cabinets (BSCs) are required in BSL-2/3 laboratories for manipulations of infectious agents that have the potential of creating aerosols. As a general rule, BSCs in laboratories are recirculating units, although they can be vented by design. Please consult with EH&S for more information.

### REQUIREMENTS

1. Biological safety cabinet guidelines:

   Biological safety cabinets, whether purchased through the WU Purchasing Department contract or as part of a building contract, shall meet all EH&S requirements.

- Directive: EH&S
- Justification: Extensive testing has shown that purchase of BSCs without generic specification requirements results in unsatisfactory units that are very expensive to maintain and may jeopardize research projects during servicing.

b. The type of cabinet to be used shall be determined during the design process by research applicability and because it may be part of the laboratory exhaust system.

- Guideline: CDC/NIH BMBL, Appendix A
- Directive: EH&S
- Justification: Not all BSCs are appropriate for a specific intended use. The EH&S must be consulted before procurement.

c. BSCs shall be located away from the laboratory door, supply air diffusers, and other high traffic areas.

- Guideline: CDC/NIH BMBL, Appendix A
- Directive: NSF 49
- Justification: The effectiveness of BSCs is compromised by outside air currents and the movement of laboratory personnel.

d. Two BSCs shall not be installed closer than 48-inches (front to front).

- Standard: NSF 49
- Justification: Laminar air flow is interrupted by concurrent operation of two cabinets within 48-inches of each other. The potential for air turbulence increases when two cabinet operators are working at the same time in the immediate vicinity.

e. All cabinets shall be NSF listed, UL approved, and installed according to manufacturer and university requirements.

- Guideline: CDC/NIH BMBL, Appendix A
- Directive: EH&S
- Justification: The cabinet manufacturer has designed BSCs that, when used and installed properly, will provide product, environmental and personnel protection. However, if a cabinet is not installed properly (e.g., if a Class II, B2 cabinet is not ducted or if a cabinet is located near supply air outlets or heat registers), it may not be serviceable. Furthermore, to install a cabinet and deviate from the listed NSF requirements will void the NSF 49 approved listing and jeopardize field certification.

f. A biosafety cabinet shall not be installed directly opposite an autoclave.

- Guideline: CDC/NIH BMBL, Appendix A
- Directive: EH&S

- Justification: The exhaust from an autoclave contains heat and moisture, that may interfere with the air barrier of the BSC. This could cause air turbulence in the BSC and adversely affect the unit's performance. There is also an increase of potential contamination within the cabinet if the autoclave is not functioning properly, since the steam may contain spores or aerosols. Furthermore, operator usage of an autoclave will create traffic in the vicinity of the cabinet air barrier, further deteriorating performance.

g. All BSL-2/3 experiments performed concurrently with minute quantities of toxic chemicals or trace amounts of radionuclides shall be done in either a Class II, Type A2 (thimble connected), or a Class II, Type B (hard ducted) BSC.

- Guideline: CDC/NIH BMBL, Appendix A
- Directive: EH&S
- Justification: A Class II, type A cabinet recirculates 70% of its air within the room, and HEPA filters do not provide protection from chemical vapors, gases or volatile radionuclides. Therefore, activities involving these materials shall be performed in a Class II, type B cabinet that has been properly vented and field-certified or in an approved Class II Type A that has been "thimble" connected to the exhaust duct work and field certified.

h. All BSCs shall be field certified when first installed in the laboratory and at least annually thereafter. They must also be recertified after relocation, filter replacement, or service within a contaminated cabinet plenum.

- Guideline: CDC/NIH BMBL, Appendix A
- Standard: NSF 49
- Directive: EH&S
- Justification: HEPA filters and gaskets inside a BSC can shift during transport and deteriorate over time, potentially allowing hazardous materials to leak from the cabinet and into the laboratory. The BSC must be tested annually to guarantee containment, as well as product and environmental protection.

i. Uncombusted natural gas shall not be introduced into a BSC atmosphere.

- Directive: EH&S
- Justification: Introduction of natural gas into a BSC atmosphere violates the prohibition against use of flammable material within a cabinet.

j. Centrifuges in BSL-2/3 laboratories shall be equipped with sealed rotor heads or used with covered safety containers. Continuous flow centrifuges or other equipment that may produce aerosols should be contained within devices that exhaust air through certified HEPA filters.

- Guideline: CDC/NIH BMBL
- Directive: EH&S

- Justification: The use of centrifuges can produce bioaerosols, and accidents involving centrifuges may result in a breach of containment and / or in laboratory-acquired infections. Therefore, standard operating practices and engineering controls must be adhered to in BSL-2/3 laboratories.

k. Vacuum lines shall be protected with liquid disinfectant traps and, for some applications, in-line HEPA filters.

- Directive: EH&S
- Justification: These features protect laboratorians and university personnel who service ancillary support equipment.

l. Compressed gas cylinders shall be secured.

- Standards: NFPA 45 and NFPA 99
- Justification: Prevents explosion hazards.

## ARCHITECTURAL CONSIDERATIONS

REQUIREMENTS

1. Architectural Considerations:

a. The laboratory shall have an aisle clearance of at least 36-inches.

- Standard: NFPA 45
- Justification: The main emergency egress shall have a minimum clearance of 36-inches to facilitate rapid departure in case of emergency.

b. Laboratory benches shall be placed at least 44-inches from an exit.

- Directive: EH&S
- Justification: Laboratory benches must not block emergency access to an egress. This directive also applies to the placement of chairs or stools.

c. The laboratory shall be fitted with sealed electrical outlets, using conduit plugs, that can accommodate the current requirements of the equipment used within. Biosafety cabinets shall be provided with 20-ampere, dedicated, top accessible electrical outlets.

- Directive: EH&S
- Justification: The laboratory may have several items of equipment that require large amounts of electrical current. Such items include freezers, biosafety cabinets, centrifuges, and incubators. Before occupancy, the room design must take electrical demand into account to avoid a potential power failure. Sealed electrical outlets help prevent transmission of contaminants and maintain air balance. All BSCs must be electrically tested annually and provided with enough electrical capacity to service interior outlets.

d. The room temperature and humidity shall be mechanically controlled via an exterior support ventilation system that produces less than 25 FPM throw velocity five-feet from any biological safety cabinet.

- Directive: EH&S
- Justification: The laboratory must be made thermally comfortable (68-72 degrees Fahrenheit dB and 30-50 percent RH) before permanent occupancy. Electrical appliances often exhaust heat into a room (e.g. REVCO freezer, incubator, autoclave), and failure to take this effect into consideration may result in an artificially warm work environment. Windows shall not be opened for a cooling effect since this will alter the room air balance and breach containment. A cool room shall not be heated with a portable heater, which may be a fire hazard. Use of fans for cooling is prohibited.

e. Circuit breakers shall be located outside the BSL-2/3 laboratory space and labeled.

- Directive: EH&S
- Justification: In the event of an emergency, the laboratory may be unsafe to enter. Therefore, labeled circuit breakers for key electrical appliances shall be located outside the laboratory.

f. Shut-off valves for gas and vacuum lines shall be located outside the laboratory, easily accessible and labeled.

- Directive: EH&S
- Justification: In the event of an emergency, the laboratory may be unsafe to enter. Therefore, valves for gas and vacuum lines shall be located outside the laboratory and properly labeled.

g. Storage of chemicals should be in accordance with The International Fire Code 2018, NFPA and OSHA. Discussion of chemical storage needs should occur early in the design process with the WUSM Project Manager.

- Directive: International Fire Code 2018, NFPA and OSHA.
- Justification: Minimum chemical storage reduces the hazard impact of chemicals coming into contact with an accidental fire. This reduces the complexity of a possible fire incident.

h. Break Rooms, and other rooms where eating or drinking activities occur, must not be located within Lab Suites.

- Directive: WUSTL Policy: Eating, Drinking, and Related Activities in Laboratories

i. Provide interstitial space above ceiling that is adequate for the regular care and maintenance of equipment.

- Directive: EH&S

j. Synthesis Laboratories should be located on lower floors of buildings due to the large number of flammable liquids used.

- Directive: EH&S

k. Final location and quantity of Autoclave(s) shall be coordinated with WUSM Project Manager and EH&S.

## CERTIFICATION AND MAINTENANCE

REQUIREMENTS

1. Certification and maintenance guidelines:

a. All biological safety cabinets in BSL-2/3 laboratories shall be certified initially before use, annually thereafter, after moving, and after filter replacement.

- Guideline: CDC/NIH BMBL, Appendix A
- Standard: NSF 49, Appendix A
- Directive: IBC and BSO
- Justification: Certification is justified to guarantee containment for the protection of laboratory personnel from laboratory-acquired infections and to guarantee product and environmental protection.

b. All BSCs shall be gas decontaminated before moving, changing filters, or repairing.

- Guideline: NIH Laboratory Safety Monograph
- Standard: NSF 49, Appendix A
- Directive: EH&S
- Justification: Decontamination protects certification personnel and all individuals involved in disposal of contaminated filters.