BIOLOGICAL SAFETY LABORATORIES

The design guidelines presented here pertain to biological research laboratories where potentially harmful microbial agents or recombinant DNA vectors and hosts are used or studied. Such "biological safety" laboratories are designed to help maintain containment appropriate to the hazard level that each agent or class of agents presents. The primary source documents for the general requirements of containment laboratory design are "Biosafety in Microbiological and Biomedical Laboratories" (BMBL), 5th or later edition (Health and Human Services Centers for Disease Control) and the NIH Guidelines for Research Involving Recombinant DNA Molecules. Risk assessment, user needs, and standards derived within the industry are the primary drivers for design and construction details. Budgetary considerations may drive the decision to construct a containment laboratory and may also limit the laboratory scope or size, but budget limitations must never be a reason to limit or decrease the containment or safety features of a containment laboratory during the design or construction processes. The campus Biological Safety Officer (BSO) is responsible for developing the risk assessment and for guiding design and construction so that the facility containment capability is consistent with the risk assessment and with the proposed research.

Biological Safety Level 1 (BSL1) laboratories exclusively handle agents that present minimal hazard to humans, plants, animals, or the environment. These laboratories are usually designed with minimal containment systems and equipment. In BSL1 laboratories containment requirements are met almost exclusively by the work practices of the user. Nearly all BSL1 work can be performed on the bench top. If required, significant product protection is usually provided by clean benches or biological safety cabinets.

Biological Safety Level 2 (BSL2) laboratories provide higher level containment systems and equipment. BSL2 labs are intended to handle agents that can cause disease in humans, animals, or plants but that may not infect target organisms easily or cause serious disease. These agents do not normally pose a significant hazard to the community including to adjacent labs and public areas within the building. A Class II Type A2 biological safety cabinet is the central engineering aerosol containment control at BSL2, and procedures that do not generate aerosols can usually be performed on the bench top.

Biological Safety Level 3 (BSL3) laboratories are designed for containment of indigenous or exotic agents that can cause serious, possibly life-threatening disease in humans, animals, or plants and can often infect by aerosol exposure. Human infectious agents normally handled at BSL3 usually present a significant hazard to the laboratory user and to the laboratory area where the work is being done, including adjacent laboratories and public spaces within the building, but rarely to the wider community except for (a) some agricultural pathogens and (b) large-scale (>10 liters) culture of human pathogens normally handled at BSL2. Because of the aerosol hazard all open work in a BSL3 laboratory is performed in a biological safety cabinet, and the laboratory design provides significant containment to protect the user, the community, and the environment from biohazardous materials. Besides the biological safety cabinet, the most important containment

features in a BSL3 laboratory are a powerful redundant single-pass air exhaust system that maintains a strong negative air flow under all conditions, and HEPA filtering of exhaust air. Wall, ceiling, and floor penetrations are limited to those required for laboratory function and they are carefully sealed to contain gaseous decontaminating agents. Although almost any laboratory with inward air flow and adequate furniture and utilities can be designed or adapted to accommodate BSL1 or BSL2 work, the BSL3 laboratory is a purpose-designed and constructed facility that requires specific features constructed in specific ways with specific commissioning requirements. An incorrectly designed or constructed BSL3 laboratory may never be usable for its intended purpose.

Biological Safety Level 4 (BSL4) laboratories are highly specialized facilities intended for work with exotic infectious agents that are capable of causing serious, often lethal human disease and for which vaccines or therapies are rarely available. Containment in a BSL4 laboratory is achieved by airtight building design combined with specialized personal protective equipment ("space suits") or by the use of glove boxes that isolate the user from the work, sometimes both. Elaborate effluent and waste decontamination systems are always provided, and exit disinfectant chemical showers are provided in laboratories that depend on "space suits" for personal protection. These laboratories are always purpose-designed and specific containment provisions depend on the project-specific risk assessments, so other than general provisions noted later they are not detailed further in this document.

BASIC DESIGN CONSIDERATIONS FOR ALL BIOLOGICAL SAFETY LABORATORIES
All biological safety laboratories must be designed to be easy to clean. Floors and walls must be durable and liquid tight. In BSL 2 laboratories, drop ceilings must use smooth, cleanable tiles (mylar face with smooth surface or equivalent). If the risk assessment permits, the walls of multiple rooms within a BSL2 laboratory suite may not be required to extend to the structural deck above, but the perimeter walls of the suite must be full height and extend to the deck.

Laboratory furniture and casework should be ergonomically designed. Fixed casework will be sealed and caulked to the walls on installation to facilitate cleaning and prevent vermin from entering. Chairs and other furniture used in laboratory work must be covered with a smooth, non-fabric material that can be easily cleaned and decontaminated. Protect exposed corners and walls from damage by carts and portable equipment.

Emergency eyewashes will be provided in laboratories. All eyewashes shall be plumbed to drain or installed over a sink. Eyewashes shall deliver potable water and must be installed in accordance with Section 224500. An emergency eyewash/safety shower will be located close to areas where there is a risk of a splash to the body.

Provide an inward flow of air from rooms/areas of low hazard into rooms/ areas of higher hazard without recirculation to spaces outside of the lab.

For BSL2 laboratories provide a locked storage area in the building for medical waste interim storage, and provide an autoclave in the building. Provide storage for chemical disinfectants, such as household bleach, ethanol, and other disinfectants as determined by the risk assessment.

BIOLOGICAL SAFETY CABINETS

Nomenclature, Features, and Applications. The type(s) of biological safety cabinet that should be chosen for new or remodeled biological safety laboratories depends entirely on project needs and risk assessment. The National Sanitation Foundation/ANSI Standard 49 (2002) groups biological safety cabinets into Classes I, II, or III and within Class II Types II-A1, II-A2, II-B1, and II-B2. All of the classes and types are in use at UC Davis but Class I and true Class II Type A1 biological safety cabinets (75 fpm face velocity, positive pressure contaminated plenums) are obsolete and should never be included in new or remodeled UC Davis laboratories. Class III biological safety cabinets are typically supplied as glove boxes which require two exhaust HEPA filters and have extremely limited application outside of BSL4 containment. Do not provide a Class III biological safety cabinet without authorization from the BSO.

The remaining biological safety cabinet classes and types include:

Class II Type A2. This is the standard biological safety cabinet used in most BSL2 and BSL3 laboratories at UC Davis and elsewhere. It is also widely used at BSL1 for non-biohazardous cell culture. Relevant features include:

- 100 fpm face velocity
- Negative pressure contaminated plena, or positive pressure contaminated plena enclosed within negative pressure plena
- 70% of the air recirculates within the cabinet (30% is exhausted)

Class II Type A2 biological safety cabinets may be constructed to recirculate HEPA-filtered exhaust air back into the laboratory or they may be supplied with an air gap (aka thimble or canopy) requiring exhaust ducting to the exterior of the building. The air gap version should never be installed without the required ducting because the exhaust HEPA filter is exposed and vulnerable to unseen damage that could result in an undetected breach of containment. Volatile materials and radionuclides may only be used in minute quantities in a Class II Type A2 biological safety cabinet that is connected to the building exhaust via an air gap. *Such materials may not be used at all* in a "recirculating" biological safety cabinet without a ducted exhaust. "Recirculating" Class II Type A2 biological safety cabinets should not be chosen for new or remodeled BSL2 or BSL3 laboratories without BSO approval. Recirculating cabinets are used primarily to accommodate new projects in existing laboratories that were not originally outfitted with a biological safety cabinet.

Class II Type B1. Class II Type B1 biological safety cabinets recirculate only 30% of the intake HEPA-filtered air into the work space, and they exhaust 70% via the rear grill, which allows greater use of volatiles, radionuclides, and toxic chemicals than does the Class II Type A2

biological safety cabinet as long as such work is confined to the rear of the biological safety cabinet work space. Relevant features:

- 100 fpm face velocity
- Negative pressure contaminated plena, or positive pressure contaminated plena enclosed within negative pressure plena
- 30% of the air recirculates within the cabinet (70% is exhausted)

Class II Type B1 biological safety cabinets must be hard ducted, usually to an independent exhaust system with the exhaust fan placed just prior to the stack. They must also be equipped with alarms to warn the user of an exhaust fan failure, and with an interlock to shut down supply air rapidly if the exhaust fails. The primary advantage of the Class II Type B1 over the Type B2 (discussed below) is that the Type B1 may be more easily integrated into a room air exhaust system but either of the Type B biological safety cabinets can be challenging in this regard. Unless the user has a specific need for a Class II Type B1 biological safety cabinet the Class II Type A2 or B2 are better choices. Do not provide a Class II Type B1 biological safety cabinet without authorization of the BSO.

Class II Type B2. Class II Type B2 ("total exhaust") biological safety cabinets exhaust 100% of the supply air through a HEPA filter to the outside without recirculation within the biological safety cabinet. These cabinets must always be hard ducted to a dedicated exhaust system. As such, they resemble a chemical fume hood-biological safety cabinet "hybrid" in function. Toxic and volatile chemicals may be used in Class II Type B2 biological safety cabinets *in conjunction with microbiological work*. Tracer amounts of radionuclides may be also be used in these cabinets, provided the Radiation Use Authorization has an approved variance allowing for such work. Class II Type B2 biological safety cabinets should not be installed in lieu of providing a standard chemical fume hood. Chemicals used in Class II Type B2 biological safety cabinets must not cause damage to the HEPA filter, filter housings, interior surfaces, or gaskets and this requirement must be discussed with the user during design development. Relevant features:

- 100 fpm face velocity
- Negative pressure contaminated plenums, or positive pressure contaminated plenums enclosed within negative pressure plenums
- 100% of the intake air is exhausted without recirculation within the biological safety cabinet

Class II Type B2 biological safety cabinets must be hard ducted, always to an independent exhaust system with the exhaust fan placed just prior to the stack. When used in BSL3 laboratories, these biological safety cabinets must be equipped with redundant exhaust fans and must be equipped with emergency power to the exhaust fans. Alarms to warn the user of an exhaust fan failure, and an interlock to shut down supply air rapidly upon exhaust failure must also be provided.

Biological Safety Cabinet Purchase and Certification. Biological safety cabinets purchased for use at UC Davis must be designed and tested to NSF/ANSI Standard 49, and must also be solidly constructed so that internal spaces and plena do not distort if the floor is uneven. Currently the only manufacturers whose biological safety cabinets are routinely approved by EH&S for purchase at UC Davis include Baker (preferred), LabConco (Delta series and successors), Forma/ThermoFisher, and NuAire. The BSO will review in advance any other proposed biological safety cabinet purchase to determine whether the proposed unit is suitable for use at UC Davis. All biological safety cabinets must be certified to NSF/ANSI Standard 49 (2009 and later revisions) specifications by technicians accredited under that standard. Biological safety cabinets must be certified at the time of manufacture and recertified after installation but before first use, annually thereafter, and any time the cabinet is moved more than one inch (2.5 cm), even if it is then returned to the original position. Biological safety cabinets must also be recertified after any internal repair.

Laminar Flow "Clean Benches". Clean benches use HEPA-filtered air flowing over the work area and exhausted via the front of the enclosure to keep products free of airborne contaminants. They offer no protection to the user and in fact expose the user directly to the products (at 90-100 fpm air velocity). They are inappropriate for any work involving hazardous materials. Clean benches should not be provided in new or remodeled facilities without the concurrence of the BSO.

Further notes:

- In the absence of specific information regarding biological safety cabinet requirements, provide stainless steel exhaust duct work, control valve and controller to support the addition of at least one Class II Type A2 thimble-connected biological safety cabinet in each new laboratory.
- The UC Davis Biological Safety Administrative Advisory Committee does not recommend the use of ultraviolet (UV) light as a decontamination method in biological safety cabinets and biological safety cabinets installed on campus should not be provided with a UV light.
- Gas, compressed air, or house vacuum shall not be plumbed to biological safety cabinets.

BIOLOGICAL SAFETY CABINET PLACEMENT

Locate the biological safety cabinet at least six feet from doors and high-traffic areas and so that air supply diffusers do not affect airflow at the biological safety cabinet face (low velocity diffusers preferred). Provide at least 12 inches of clearance above the biological safety cabinet for testing and decontamination of HEPA filters. Install six inches out from the rear wall to allow for cleaning. Ensure that adequate electrical power is available within six feet of the biological safety cabinet.

BASIC LABORATORY DESIGN FOR BIOLOGICAL SAFETY LEVEL 3

Under NIH standards, the laboratory design professional must use the current edition of the BMBL as the basis of design. See Section 115300 (Laboratory Equipment) for more information. BSL3 laboratory planning must include the campus Biological Safety Officer and a qualified BSL3 specialist commissioning agent from the outset and during all stages of design development and construction. The design professional and the BSO work closely with the commissioning agent to ensure that all containment systems function as intended, which helps greatly to avoid design and construction errors and to avoid project completion delays and overruns. BSL3 laboratories for which specific scientific projects have not yet been identified must generally be designed to be as versatile as possible to accommodate a wide spectrum of potential future activities with minimal refurbishment--significant refurbishment and remodeling of existing BSL3 space to accommodate new projects may be prohibitively expensive and impractical. In the university environment a BSL3 laboratory is also very likely to change "owners" several times over the years and to support a variety of types of projects during its lifetime. Thus, it is always advisable to design and build more breadth and versatility into such laboratories than the initial scientific project might warrant.

General

1. The laboratory suite is composed of an anteroom complex and lab rooms. Access to the lab is via anteroom/change room (at least two doors between general access areas and the BSL3 work area). Provide a decontamination room for large equipment to leave the lab. If possible, provide a separate equipment room to isolate heat load such as supercold freezers and high hazard equipment such as centrifuges, or a shared prep room within the lab. At a minimum the anteroom complex should include an airlock, a clean change room, a shower, and a dirty change room. The shower may be incorporated into the dirty change room as long as it is easy to step from the shower into the clean change room without contacting the walls and floor of the dirty change room.
2. A risk assessment may require an emergency shower within the suite, although the exit shower required in these laboratories may substitute for an emergency shower if it is close enough to the work area.
3. The suite has effectively gas-tight walls, ceilings and floors (i.e., capable of containing decontamination gas during the decontamination process); allow air gaps under and around doors for make-up air. High quality room construction with carefully silicone-sealed joints, seams, utility boxes, and other penetrations, penetrations limited to utilities within the room, and specially selected and professionally applied epoxy wall and ceiling coatings and finishes. Work surfaces, floors, walls and ceiling are designed, constructed, and finished to facilitate easy cleaning and decontamination, so that floors and ceilings are monolithic and walls and ceilings are finished with a dead smooth epoxy coating that is easy to clean and maintain. Avoid unnecessary horizontal or vertical surfaces that can collect contaminants (e.g., unistrut, surface mounted conduit).
4. All walls within and on the perimeter of a BSL3 suite must reach the structural deck above regardless of ceiling height.

5. If the BSL3 suite must be located on an exterior wall due to programmatic, ceiling, or construction constraints, the suite will be constructed as a "room within a room" without load-bearing walls and including an air gap to preclude extremes of temperature to the walls. Fluctuations of temperature on the walls of the suite, not internal to the building, can cause finish cracking and gaps can open in the wall finish, creating a leak path for contamination.
6. No floor penetrations that are not locally essential to the BSL3 laboratory operation are permitted within the containment envelope above or below the ceiling.
7. Air flows unidirectionally from low hazard space into higher hazard space and is always single-pass.
8. All tall or heavy fixtures and equipment (e.g.: biological safety cabinets, autoclaves, etc.) should be fitted with a seismic anchoring system/device engineered to withstand earthquake stresses equal to 7.0 on the Richter scale.
9. All shutoffs (steam, water, natural gas) will be external to containment. Secondary shutoffs may be provided inside containment but they must be accessible without opening hatches or panels and their penetrations must be sealed carefully with silicone. Access to fixed equipment requiring maintenance (autoclaves, HVAC components, lighting fixtures, video surveillance cameras) must be completely outside containment. Plumb CO_2 and other specialty gases from outside of the containment envelope.
10. Provide a comfortable temperature compensating for the heat load from equipment and for the gowning requirements for personnel in the lab.
11. The facility must pass third-party commissioning, with oversight from the BSO, to verify that design and operational parameters have been met.

Location

1. The BSL3 laboratory complex should be located in one of the top two floors of the building if the mechanical systems are to be installed outside on the roof, or be sited immediately below a penthouse mechanical systems support space at least as large as the laboratory suite footprint. This will minimize dedicated contaminated exhaust duct runs and allow easy access for mechanical systems maintenance and for changing light bulbs from outside of containment. Animal BSL3 facilities may be located as necessary to facilitate animal care requirements but support space must be readily accessible from outside of containment.
2. BSL3 suites must be located away from public areas, separated from unrestricted traffic. See note above regarding anteroom doors.
3. No entry into anterooms from the outdoors (dirt and contamination problems).
4. BSL3 suites must be located away from areas that could impact directional airflow or differential pressure maintenance. Elevators, exterior doors, labs with variable air volume systems or night set-backs, exterior walls with high wind load or temperature swing can cause unacceptable pressure fluctuations.

Anteroom Complex

1. See discussion above regarding anteroom components (change rooms, shower, etc).
2. Provide access to the suite through at least two (2) doors.
3. Provide doors that are alarmed so only one door may be opened at a time without sounding an alarm. Consult with the Campus Fire Marshal regarding specific allowances and requirements for interlocks, delays, and alarms.
4. The anteroom is negatively pressurized to the corridor and positively pressured to the BSL3 work area with a volumetric offset of 5 to 10% or at least 100 cubic feet per minute (cfm).
5. The anteroom suite should be large enough to:
    a. Provide a shower.
    b. Provide a hands-free sink for anterooms accessed directly by a single exit door from the BSL3 work area.
    c. Provide storage of clean gowns, laboratory coats or scrubs that must be donned before entry and be removed before leaving the suite.
    d. Minimize turbulent air currents formed when opening doors.
    e. Provide space for a log book and wall calendar.
6. Space shall be provided on or near the door for the conspicuous posting of the biohazard warning symbol, a list of emergency contacts, and access rules.

Provisions for Room and Equipment Decontamination

1. Provide a room between building non-containment and the full containment area that is large enough to accommodate the largest single piece of equipment likely to be installed in the BSL3 laboratory (usually a six-foot Class II biological safety cabinet).
2. The decontamination room should include a lockable door between the room and the BSL3 laboratory and between the room and the non-containment space outside of the suite.
3. The airflow in the equipment decontamination room must be negative to areas outside of containment and slightly positive to the biocontainment area of the laboratory.
4. Provide two 1.5" stainless steel pipes ("VHP ports") with appropriate flange fittings through the wall adjacent to the door of the decontamination room to interface a standard vaporized hydrogen peroxide generator. The pipes should penetrate the wall within 15 inches of one another and be sited no more than five (5) feet above the floor.
5. Provide similar VHP piping in the wall between the first anteroom section and the remaining anteroom sections and if possible between the first anteroom and the BSL3 laboratory.
6. Verify that all pipe penetrations are sealed to be airtight.

Floors

1. Easily cleaned, chemically resistant with a slip-resistant, smooth, hard finish, impermeable to liquids, monolithic/seamless. Slightly roughened epoxy to prevent slippage is the preferred alternative--seamless high-strength vinyl is also allowed with BSO approval.
2. Coved up the wall (4 inches) and caulked at the flooring-to-wall junction. Flooring will be installed and caulked before casework is installed so the floor extends underneath casework to provide good containment for spills.
3. Ceramic tile and grout are not permitted as floor material in BSL3. Grout cannot be properly cleaned or decontaminated to maintain containment.

Walls

1. Solid concrete or grouted concrete block walls are preferred (conduit and pipe locations must be planned carefully so that these channels are provided prior to concrete pour or block grouting). These achieve a "room within a room," but none may be bearing wall and the wall to ceiling joint must be gas-tight. Alternatively, hollow walls may be used if they reach the structural deck above and are fully sealed so that they are not contiguous with interstitial air space outside of containment.
2. Hollow walls must be durable (gypsum board), washable, and resistant to detergents and disinfectants.
3. Use durable glossy epoxy paint over a dead smooth epoxy surface coating that is compatible chemically and physically with the topcoats.
4. Round exposed casework corners and provide carefully sealed wall bumpers in cart storage sites to protect corners and walls from damage by carts.
5. Wall and ceiling penetrations are limited only to those necessary for the immediate operation of the facility. Pass-through pipes, hatches, access panels, circuit panels, etc. are strictly forbidden anywhere in the BSL3 suite including the anteroom complex. All penetrations are sealed with non-rigid, non-shrinking fire retardant sealant followed by durable silicone sealant. Utility boxes are meticulously sealed with fluid silicone at all seams and conduit junctions inside the box and around the perimeter of the box. Face gaskets and spray foam sealants are not acceptable methods to seal utility boxes.
6. Locate the BSL3 interior to the building, and design and construct with non-bearing walls.
7. Wall to wall, wall to flooring, wall to ceiling, and wall to casework corners will be caulked.
8. Carefully sealed radiused corners and joints are optimum for easy cleaning.
9. Penetrations shall be horizontal, located as close to the site where needed as possible. Utility boxes must be recessed fully in hollow walls.
10. Unistrut and wiremold shall not be used in a BSL3 laboratory except where authorized by the BSO. When used, these devices must be caulked to the walls along the top and side junctions. Wall penetrations inside wiremold must be minimized and sealed gas tight before the wiremold is installed.

11. Exposed conduit or pipe is permitted only over block or concrete walls. Exposed conduit pipe runs must be vertical, caulked between the wall and conduit or pipe, and as short as possible.

Ceiling

1. Washable, resistant to detergents/disinfectants.
2. Durable glossy epoxy paint compatible chemically and physically with a required smooth epoxy undercoating.
3. Must be structurally compatible with the walls for maximum stability, and capable of being sealed gas tight permanently to the walls.
4. Hard, monolithic construction - gypsum board or concrete, not removable tile.
5. Access panels and hatches are not permitted within the BSL3 suite, including within the anterooms.
6. A ceiling height of 10 feet is required. This provides the 12 inches of clearance above Class II Types A2 and B2 biological safety cabinets required by NSF/ANSI-49. However, ceilings must not exceed 10 feet unless required for the project and the risk assessment allows.

Doors

1. Solid doors required.
2. A window of up to 50% of the door area may be included in any BSL3 suite door and should be included in the last door between the anteroom complex and the main laboratory.
3. Self-closing.
4. Locking. Provide standard key locks and security locks such as card key, at first anteroom door from public area and at each laboratory door in a multiple laboratory suite.
5. Open inward. Sliding doors are not usually allowed because of the complex frame surfaces that require special effort to clean.
6. Have required fire ratings.
7. Doors and frames of solid finish construction.
8. Door openings sized to allow passage of large equipment.
9. Recommend wall-frame connection be made air tight at time of frame installation. Door frames must be embedded in silicone sealant and caulked thoroughly around the outside seam.
10. Install non-sealing door sweep such as hair sweeps on door between anteroom and corridor to exclude crawling insects and vermin but to allow airflow.
11. Panic door hardware shall be mounted externally, not contained within the door. The door frame must not be drilled to accommodate panic hardware bars—fittings to accommodate the bars may be attached externally to the frame if the fastener holes are sealed with silicone during installation.
12. Magnehelic or photohelic gauges or some other quantitative visual means for verifying negative air flow from external to containment shall be provided at the door from the

outside into the anteroom complex and at the last door in the anteroom complex into the BSL3 work area. The gauges shall be sited at eye level so that they can be read easily from outside, without opening the door.

Windows

Avoid; if required, the following apply (see note about windows within doors above).

1. Be installed gas-tight
2. Windows to permit view between rooms must be safety glass, permanently closed and silicone sealed.
3. Slope interior sills (including door windows).

Eyewash/Safety Shower

1. Emergency eyewash, plumbed to drain or installed over a sink, is located in each BSL3 room.
2. A combination emergency eyewash/safety shower unit shall be located close to sites where laboratory users are exposed to splash hazards. Alternatively, an eyewash with a hand-held drench hose as a separate unit may be installed. Contact the campus Chemical Safety Officer for advice.
3. Emergency eyewash and emergency eyewash/safety shower units will be sited and installed in accordance with Section 224500.
4. Tempering valves are not required.

Shower Entry/Exit

1. An entry/exit shower will be provided in the anteroom complex of the BSL3 suite.
2. The shower will be pass-through in design so that traffic flow is separated and dirty clothing/PPE will not contaminate clean clothing, people or equipment.
3. Eight (8) square feet of space should be provided for a laundry hamper.

Plumbing

1. See discussion above in "walls" regarding penetrations.
2. All penetrations are perpendicular to the surface and are caulked to be gas tight. No penetrations that are not part of the immediate BSL3 suite operations requirement are permitted.
3. All pipes into the BSL3 suite from hollow walls are secured inside wall to prevent movement.
4. Pipes external to solid walls must run vertically and be caulked between pipe and wall.
5. Provide fixtures resistant to bleach corrosion and other disinfectants and decontaminants (e.g., vaporized hydrogen peroxide – VHP).
6. Back-flow prevention on all faucets, even if on industrial water.
   Locate water supply control shutoff outside biocontainment area—inside containment under-sink shutoffs are permitted.

Sinks and Drains

1. Handwashing sinks shall be located in each BSL3 work area room near the exit.
2. Handwashing sinks shall also be provided in at least one change room of the anteroom complex (see discussion above about sinks in rooms accessed directly from the BSL3 work area).
3. Sinks should dispense potable water.
4. Sinks must be either hands-free or automatically operated. The preferred alternative is foot pedals placed close to the floor and just exterior to the cabinet, with mixing valve integral with the pedals. Photocell actuated hands-free operation is a non-preferred alternative because of potential undetected leakage in the mixing valve that can damage adjacent walls and breach containment.
5. A wall-mounted paper towel dispenser and a wall-mounted hands-free soap dispenser should be installed above the sink.
6. Hot & cold water from a pre-mixing faucet or mixing valve as noted above.
7. Backsplash is oversized and coved at the base to facilitate cleaning.
8. Sinks must have disinfectant/chemical-resistant traps.
9. Drains from the BSL3 suite must go directly to sanitary sewer and not intersect with other drains from outside of containment.
10. All exposed drains upstream of the sanitary sewer line connection to be labeled with the universal biohazard sticker and with the notation that the effluent comes from a BSL3 laboratory.
11. Provisions for effluent decontamination will be provided. The provisions for effluent decontamination will be based on project needs and the BSO risk assessment and range from work practices such as adding bleach to the trap to engineering measures such as chemical or heat decontamination tanks.

Autoclave

1. Pass-through to anteroom or support room outside of containment.
2. Body of autoclave located outside of containment to provide easy access for maintenance.
3. Autoclave has control panels internal and external to containment; has gravity and liquid cycles; is of sufficient size to handle waste coming from the lab.
4. The autoclave controls are interlocked so that both doors cannot be open simultaneously.
5. The outside door can only be opened if the autoclave has cycled successfully.
6. Use a bioseal or other equivalent means to create a seal at the containment wall.
7. Floor penetrations, if essential, shall have a water and gas-tight seal at the monolithic floor; the discharge shall have an integral effluent decontamination system (verify with BSO).
8. The floor under autoclave shall be monolithic, seamless, coved and water-tight.
9. Walls and ceiling will be monolithic, sealed dead smooth and covered with epoxy paint.
10. Access to repair autoclave shall be from outside the containment zone.
11. Sufficient space adjacent to contaminated door for waste collection.

12. Insulate exposed pipes.
13. A corrosion-resistant basin is provided to prevent leakage.
14. Stainless steel canopy hoods are provided over the inside and outside doors of the autoclave to contain heat and steam. The canopy over the inside door shall exhaust through the HEPA-filtered laboratory exhaust.
15. The autoclave shall be seismically anchored.
16. The installation is signed off by a professional engineer.

Life Safety

1. Fire alarms shall be clearly audible above the noise of the lab.
2. Install a wall mounted ABC Dry Chemical (4-A: 60-B:C) Fire Extinguisher near the exit door of the anteroom. Fire extinguishers should generally not be installed within the containment laboratory.
3. Lab-safe refrigerators are required to store flammable/combustible materials.

Alarms Provided For

1. Fire alarm.
2. Ventilation failure.
3. Biological safety cabinet exhaust failure.
4. -80° freezer failure.
5. Differential pressures above -0.05 "Wg *or as determined to be appropriate* during laboratory commissioning.
6. Provide audio and visual (stroboscopic) alarms that can be seen and heard throughout the suite.
7. Local alarms should be distinguishable from one other so that the source of failure can be easily identified.
8. On UPS power.
9. All alarms must be audible locally and must be wired to be monitored at the Facilities Management Alarm Shop.
10. Alarm system should allow cellular telephone notification to designated individuals.

Vacuum Systems/Pumps

1. Lines HEPA filtered in the laboratory.
2. House vacuum will not be provided to BSL3 suites. If vacuum is needed, small portable vacuum pumps will provide vacuum. Locate the pump in the laboratory. Exhaust from the vacuum pump will be HEPA-filtered.

Electrical

1. Provide emergency power to exhaust fans, lighting, biological safety cabinets, incubators, and storage freezers at a minimum.
2. Provide UPS power to alarms and to the biological safety cabinets.
3. Independent circuit for each biological safety cabinet.

4. Wall/ceiling penetrations kept to a minimum and sealed with fire retardant material (i.e., 3M CP-25 or equal) then over-sealed with silicone caulk.
5. The electrical system shall not reduce the air-tight integrity of the facility. Components will be sealed with silicone caulk.
6. Electrical boxes are cast and/or sealed air tight with silicone caulk. See the discussion above regarding utility box sealing.
7. Light fixtures are preferably accessible only from above (outside of containment) for bulb-changing. Alternatively they may be surface-mounted or flush mounted if designed and sealed to maintain the suite's gas tight requirements.
8. Circuit breakers and panels must be located outside containment and labeled.

Heating, Ventilation, and Air Conditioning (HVAC) Systems

1. No recirculation of exhaust air – 100% of the air shall exhaust to the outside.
2. Dedicated exhaust system is required.
3. An exhaust HEPA filter is required (see HEPA filter section).
4. An automatically operated gas-tight ("bubble-tight") damper shall be provided in the supply ducting to isolate the supply system and prevent duct damage and puff-back in case of a supply failure. To allow selective decontamination of individual rooms within the laboratory such a damper should be provided for each room within the containment envelope.
5. Redundant exhaust fans must be provided for room exhaust and for Class II Type B biological safety cabinets.
6. Class II Type B2 biological safety cabinets exhaust must be independent of room exhaust.
7. Air supply and exhaust system capacity ≥ 125% of the suite's requirements.
8. The systems shall create directional airflow drawing air from rooms/areas of low hazard into rooms/ areas of higher hazard.
9. Negative air pressure may be provided by designing for 10% more cfm of exhaust airflow than the supply air, or sufficient to maintain the differential pressure between rooms between 0.05 – 0.20 " Wg as determined during design and commissioning phases.
10. The air balance accommodates biological safety cabinets thimble exhaust or hard duct requirements.
11. Negative air pressure is verified before entry. Install a device(s) to indicate/confirm directional airflow into the suite (e.g. 0.05 – 0.20" Wg magnehelic gauges, digital differential pressure monitors, or both). See discussion above regarding placement of these indicator gauges.
12. Assure the BSL3 suite cannot become positively pressured if the exhaust system fails – supply/exhaust interlock verified during commissioning.
13. Gas-tight dampers on the supply side shall be pneumatically operated and capable of closing completely soon enough after exhaust failure to prevent positive pressurization in the affected rooms (<10 second delay between exhaust failure and full valve closure).

14. Visual and audible ventilation system failure alarm required, monitored locally and in the Facilities Management Alarm Shop. Ventilation system failure notification should also be transmitted to cellular telephones or pagers of designated individuals.
15. Locate air supply diffusers so that airflow at the biological safety cabinet face is unaffected (laminar diffusers at least six feet from the biological safety cabinet sash preferred).
16. Ductwork in interstitial or support space is exposed to stand clear of walls to allow for cleaning, maintenance, and leak testing.
17. All exhaust ductwork upstream of the HEPA filter housing to be labeled with the universal biohazard sticker and with the notation that the exhaust comes from a BSL3 laboratory.
18. Exhaust ductwork is gas tight stainless steel with gas-tight welded joints, tested prior to installation and again when integrated into the exhaust system.
19. Where possible exhaust flow control devices (e.g., Phoenix valves) placement to be downstream (clean side) of the HEPA filter housing. Stainless steel valves are preferred where the valve placement must be upstream of the HEPA filter housing (to accommodate multiple exhaust ducts).
20. Fan coil units for supplemental cooling do not impact cleaning or breach biocontainment.

HEPA Filters

1. An exhaust air HEPA filtration system will be provided for all BSL3 laboratories.
2. Supply air will be HEPA-filtered in any agricultural, plant, or disease vector BSL3 facility.
3. A supply side HEPA filtration system should be considered for use as back draft protection in any BSL3 air handling system that is integrated with non-containment air supply. Alternatively, provide a gas-tight damper on the supply side interlocked to fail closed if the air handler fails.
4. HEPA filter housings shall be "bag-in, bag-out" and must include gas-tight dampers upstream and downstream of the housing. The dampers should be manually operated and capable of incomplete closure to allow slight air movement during decontamination. The HEPA filter housing must include ports to accommodate gas decontamination and filter testing equipment.
5. Basis of design and quality of construction and materials for HEPA filter housings shall be Flanders.
6. HEPA housings will provide for a pre-filter.
7. The HEPA housing will incorporate a HEPA filter "scan rack" with required enclosure and associated hardware.
8. Magnehelic gauges or other pressure-monitoring devices shall be installed to measure pressure drop across the HEPA filters with the display placed in the most accessible location that is practical.
9. A HEPA system is required on the autoclave exhaust, ultracentrifuge vent, vacuum pump vent, sewer vent, and canopy (thimble) connected biological safety cabinet ducting.

Lab Furniture and Casework

1. Minimize built-ins; consider moveable furniture with minimal wall and floor connections.
2. Capable of supporting anticipated loads and uses.
3. Spaced so that areas under benches, cabinets and equipment shall be accessible for cleaning; allow 6" room beneath for cleaning or cove floor up at least 4" at cabinets and benches.
4. Bench tops are impervious to water and resistant to acids, alkalis, organic solvents and moderate heat (epoxy resin).
5. Be sealed and caulked to the walls on installation to facilitate cleaning and prevent harborage for vermin.
6. Chairs and other furniture must be covered with a non-fabric material that can be easily decontaminated.
7. Tall cabinets/shelves are permanently installed or seismically anchored.
8. Cabinets/shelves have angled tops or are built up to ceiling to facilitate cleaning.
9. Joints at walls or elevation changes are coved to facilitate cleaning.
10. Sink cabinets must be open in the back to provide free access to plumbing penetrations.
11. Consider providing open cabinetry (no doors) for the sink cabinets so that plumbing leaks will be easily detected.

Security

1. Access to the BSL 3 building or BSL 3 suite shall be controlled. In addition, a security system should be installed to limit access and record entry with time, date and person. Card scan, key-pad entry with codes unique to each worker, or a biometric system such as palm or iris scan can be used.
2. All equipment (refrigerators, freezers, incubators) must be lockable, with the exception of the biological safety cabinets.
3. A closed-circuit video recording system may be required depending on a security risk assessment. If required, the cameras in the biocontainment area should be mounted inside sealed enclosures that are only accessed from outside of containment.

Communications

1. A hands-free telephone system shall be installed within the containment work area so workers can communicate to others in other parts of the BSL3 and with individuals outside of the laboratory in the event of emergency.
2. Space shall be provided within the containment envelope for a FAX device and for data entry keyboard, monitor, and networked computer. Telephone and network connections shall be provided for these devices.
3. The telecommunications/computer systems shall not reduce the air-tight integrity for the facility. All communications penetrations to be sealed meticulously with silicone caulk.
4. Wall/ceiling penetrations shall be kept to a minimum and sealed with fire retardant material and over-sealed with silicone caulk.

Commissioning

1. A qualified BSL3 commissioning agent (CxA), approved by the BSO, shall be retained at the project outset and shall participate in all downstream phases of the project development up to and including project turnover. The CxA shall develop appropriate commissioning documents after the project schematic design and equipment selection is complete, and will conduct or oversee (in the presence of the BSO as appropriate and necessary), testing for all equipment, components, and materials prior to installation. The CxA will also document all BSL3 containment and ancillary systems as built and will provide a fully operational, documented, safe BSL3 facility as the commissioning goal. The CxA will develop training programs and assist in training Facilities Management and other staff employees in the specific BSL3 facility equipment maintenance and repair.
2. Class II biological safety cabinets must be certified in accordance with NSF Std. 49 after the biological safety cabinets are installed or moved.
3. Integrity of containment envelope seals shall be demonstrated by visual inspection and by smoke testing. Pressure decay testing may be required for some facilities, based on agency requirements and BSO risk assessment
4. All air supply and exhaust ductwork shall be verified to have bubble-tight dampers where required as discussed in the previous sections.
5. All HEPA filters shall be tested to meet required specifications after installation.
6. The autoclave installation shall be found to be proper as attested by the sign-off of a professional Engineer.
7. The autoclave shall be tested to verify that it meets specified standards after installation by the calibration of thermometers and timers and by the use of biological indicators.
8. The ventilation system shall be tested by:
    a. Ductwork pressure testing to verify the integrity of gas-tight seams and welds (ASHRAE std 126).
    b. Measurement of airflow at each supply and exhaust.
    c. Smoke testing to verify limited turbulence at the face of biological safety cabinets.
    d. Smoke testing to verify airflow from areas of low hazard to areas of higher hazard, include flow direction potential disruption when opening doors.
    e. Verification that alarm systems for air system failure (exhaust, supply, room pressure) and biological safety cabinets function and annunciate properly locally, at the Facilities Management Alarm Shop, and on personal communications devices.
    f. Ventilation air balance report shall be provided to the BSO.
    g. Fire alarm systems shall be verified.
    h. The operation of backflow preventers shall be verified.
    i. Proper operation of failure interlocks shall be verified. Maintenance of pressure relationships during exhaust failure mode shall be verified. The BSO and CxA will determine appropriate testing methods and acceptance criteria for each project.

Other
Some BSL3 facilities will require significant additional systems or testing such as effluent decontamination and pressure decay testing depending on the risk assessment. BSL3 facilities constructed with NIH or USDA funding may be required to comply with specifications in the respective agency containment facility manuals which may be more specific and stringent than those detailed in this design guide.

ANIMAL BIOLOGICAL SAFETY LEVEL 3
Animal biological safety level 3 (ABSL3) facilities combine the containment and safety features of the biological safety level 3 research laboratory as detailed previously, with the special requirements for animal care in the context of infectious disease research. Exhaust ducting should be provided for ventilated caging systems, and doors into the animal rooms must always open inward, but other details are similar to those discussed above for SBL3 laboratories. Floor drains are almost always provided, but they are typically kept filled (by the user) with bleach or other disinfectant. Because housing and husbandry requirements differ so much among animal species, ABSL3 facilities must be purpose-built at least with regard to species and numbers of individuals intended to be housed. This consideration largely dictates the equipment that must be provided for and the floor plan of the facility. ABSL3 facilities designed for housing livestock or other animals larger than about 50 pounds body weight are considered primary containment devices because of the difficulty of isolating such species behind containment barriers. The design goal is to provide a building-sized biological safety cabinet and to protect the individuals using the facility with extensive personal protective equipment including respirators. These highly specialized facilities are usually classified as "BSL3-Ag" and are currently extremely uncommon.

BIOLOGICAL SAFETY LEVEL 4
Biological Safety Level 4 facilities are designed either as "glove labs" or as "suit labs." In the glove lab all work areas and equipment are isolated in airtight enclosures with two HEPA filters in series serving the exhaust air ducting. The enclosures are accessed by inserting the hands and arms into long thick neoprene gloves and reaching into the enclosures. User contamination should not be possible as long as the gloves remain undamaged. Workers in the suit lab don zippered plastic "space suits" with air supplied via external hoses and quick connects. The workers use standard Class II biological safety cabinets, usually hard ducted and with secondarily HEPA filtered exhaust. An individual leaving the laboratory takes a chemical disinfectant shower and then doffs the protective suit. Airflow within the enclosures in the glove lab and within the entire suit lab is negative, and the exhaust and supply air is HEPA filtered. BSL4 laboratories invariably require effluent decontamination. Further detail on BSL4 facilities is beyond the scope of this document - contact the BSO for guidance.

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